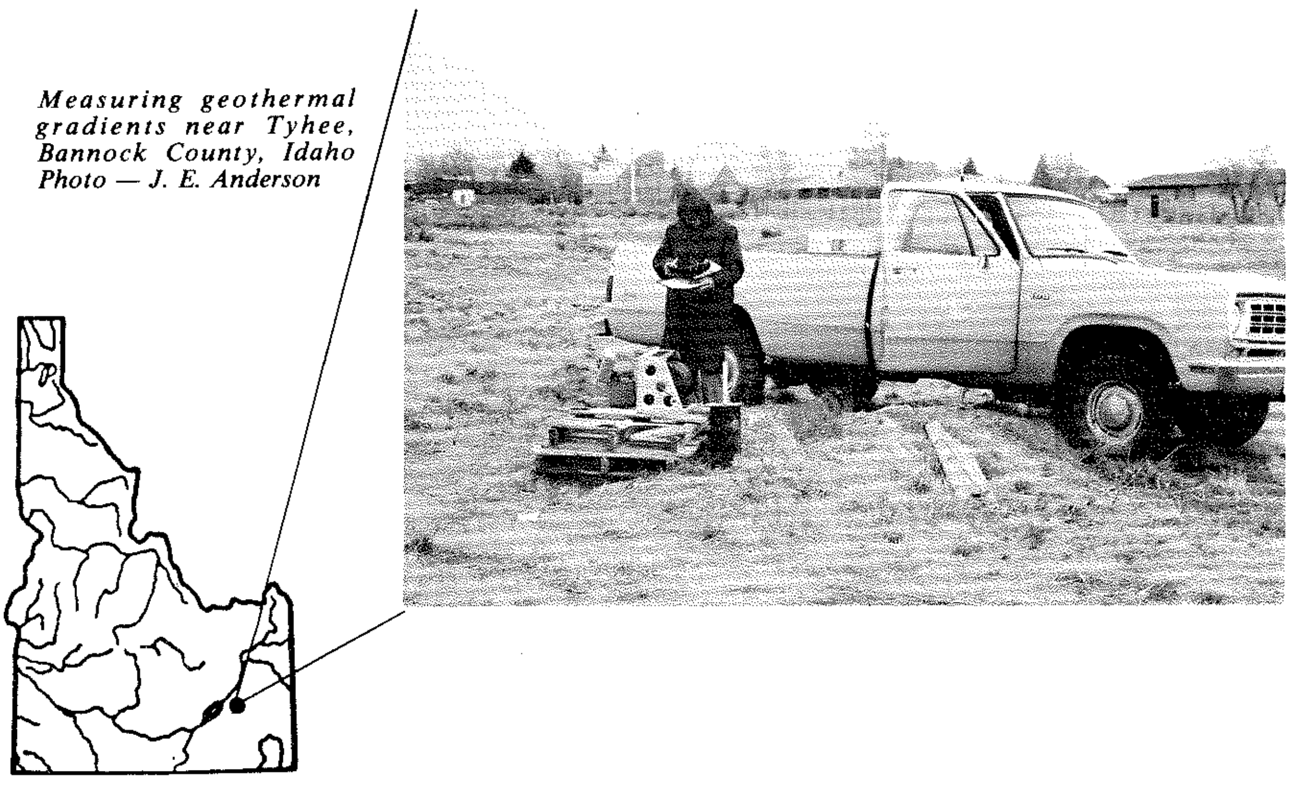
GEOTHERMAL INVESTIGATIONS IN IDAHO

Part 10

AN EVALUATION OF THERMAL WATER OCCURRENCES IN THE TYHEE AREA, BANNOCK COUNTY, IDAHO

Measuring geothermal gradients near Tyhee, Bannock County, Idaho
Photo — J. E. Anderson



IDAHO DEPARTMENT OF WATER RESOURCES

WATER INFORMATION BULLETIN NO. 30

DECEMBER 1980

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An Evaluation of Thermal Water Occurrences in the Tyhee Area, Bannock County, Idaho

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by

Marshall K. Corbett
Department of Geology
Idaho State University

and

John E. Anderson
John C. Mitchell
Idaho Department of Water Resources

Work performed under U.S. Department of Energy Contract
No. DE-AS07-77ET28407
Modification No. A003
Designation DOE/ET/01834-3

Idaho Department of Water Resources
Statehouse
Boise, Idaho

December 1980

NOTICE

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INTRODUCTION

PURPOSE AND SCOPE

For several years residents of the Tyhee area have reported encountering warm to hot waters in certain shallow wells drilled for home and/or irrigation purposes. Based on these reports and regional evaluations of the geothermal potential of southern Idaho, the Department of Water Resources recognized the need for further evaluation of the Tyhee area as a possible geothermal site, particularly its potential for home heating purposes, since the area lies in close proximity to a moderate-sized urban community.

The area under study included approximately 72 sq km (28 sq mi) of the Tyhee portion of Bannock County, an area marginal to the Snake River Plain immediately northwest of Pocatello, Idaho. See figure 1 for location. Both gravity maps, with profiles, and magnetic maps of this area have been prepared. This report attempts to interpret this geophysical data in terms of surface and subsurface geological conditions.

Both the gravity and magnetic studies reported here were initiated primarily to assist in properly locating a possible geothermal exploration hole. It was anticipated that these surveys would supplement other studies and provide badly needed subsurface geologic information essential to the determination of a probable source of reported hot waters. The type and location of major faulting in the area, the general structural and/or stratigraphic configuration of the area, and pertinent information concerning the nature and extent of the Snake River Plain boundary are thus topics of major concern to be addressed based on results of the surveys conducted.

In addition to gravity and magnetic surveys, a limited geochemical survey was conducted in order to obtain more information on water quality and aquifer temperature. Shallow subsurface geologic and hydrologic data were obtained from existing well logs to determine aquifer and shallow subsurface structure. Enhanced Landsat false color infrared imagery was also studied to detect evidence of major structural features which could control thermal water in the area. Geologic mapping was taken from existing maps augmented by field visits to acquire more information on possible faults observed on the Landsat imagery and in the subsurface geologic and hydrologic data. Temperature gradients were obtained from existing unused drill holes.

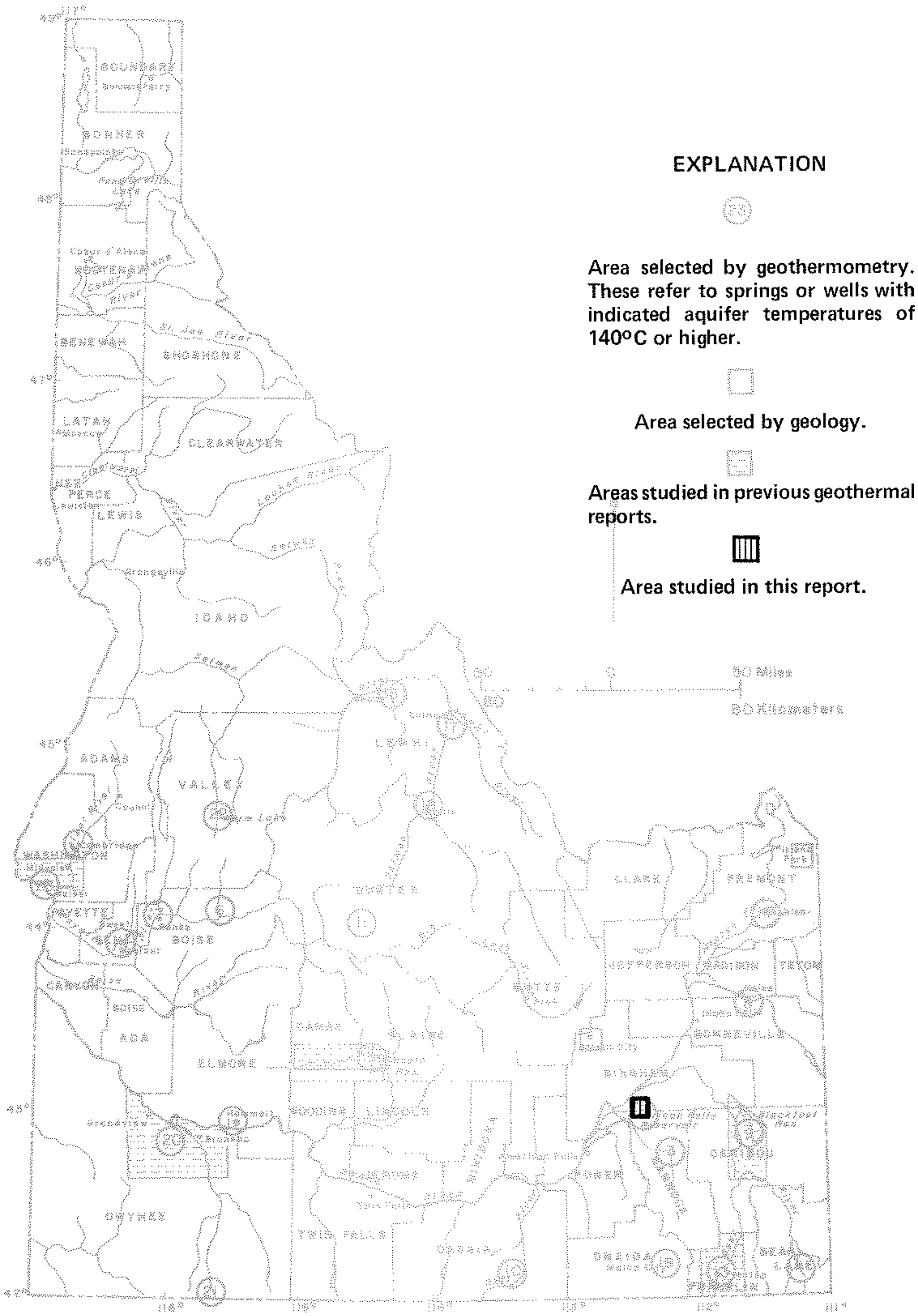


FIGURE 1. Index map showing area covered by this report and areas selected for study by Young and Mitchell (1973).

Limited funding prevented further geophysical work such as refractive or reflective seismic surveys or magnetotelluric studies which might give more definitive information about the deeper structure.

WELL-AND-SPRING NUMBERING SYSTEM

The numbering system used by the Idaho Department of Water Resources and the U.S. Geological Survey in Idaho indicates the location of wells or springs within the official rectangular subdivision of the public lands, with reference to the Boise base line and Meridian. The first two segments of the number designate the township and range. The third segment gives the section number, followed by three letters and numeral, which indicate the quarter section, the 40-acre tract, the 10-acre tract, and the serial number of the well within the tract, respectively. Quarter sections are lettered a, b, c and d in counterclockwise order from the northeast quarter of each section (figure 2). Within the quarter sections, 40-acre and 10-acre tracts are lettered in the same manner. Well 5S-34E-26dabl is in the NW1/4 NE1/4 SE1/4 of Section 26, T.5 S, R.34 E and was the first well inventoried in that tract. Springs are designated by the letter "S" following the last numeral; for example 5S-34E-27dablS.

USE OF METRIC UNITS

The metric or International System (SI) of units is used in this report to present water chemistry data. Concentrations of chemical substances dissolved in the water are given in milligrams per liter (mg/l) rather than in parts per million (ppm) as in some previous Water Information Bulletins. Numerical values for chemical concentrations are essentially equal whether reported in mg/l or ppm for the range of values reported in this report. Water temperatures are given in degrees Celsius ($^{\circ}C$). Conversion of $^{\circ}C$ to $^{\circ}F$ (degrees Fahrenheit) is based on the equation, $^{\circ}F = 1.8\ ^{\circ}C + 32$. Figure 3 shows the relation between degrees Celsius and degrees Fahrenheit.

Linear measurements (inches, feet, yards, miles) are given in their corresponding metric units (millimeters, meters, kilometers). Weight and volume measurements are also given in their corresponding metric units. Table 1 gives conversion factors for these units. Area measurements are listed in both SI and English units except when referring to areas described by official rectangular subdivision of public lands.

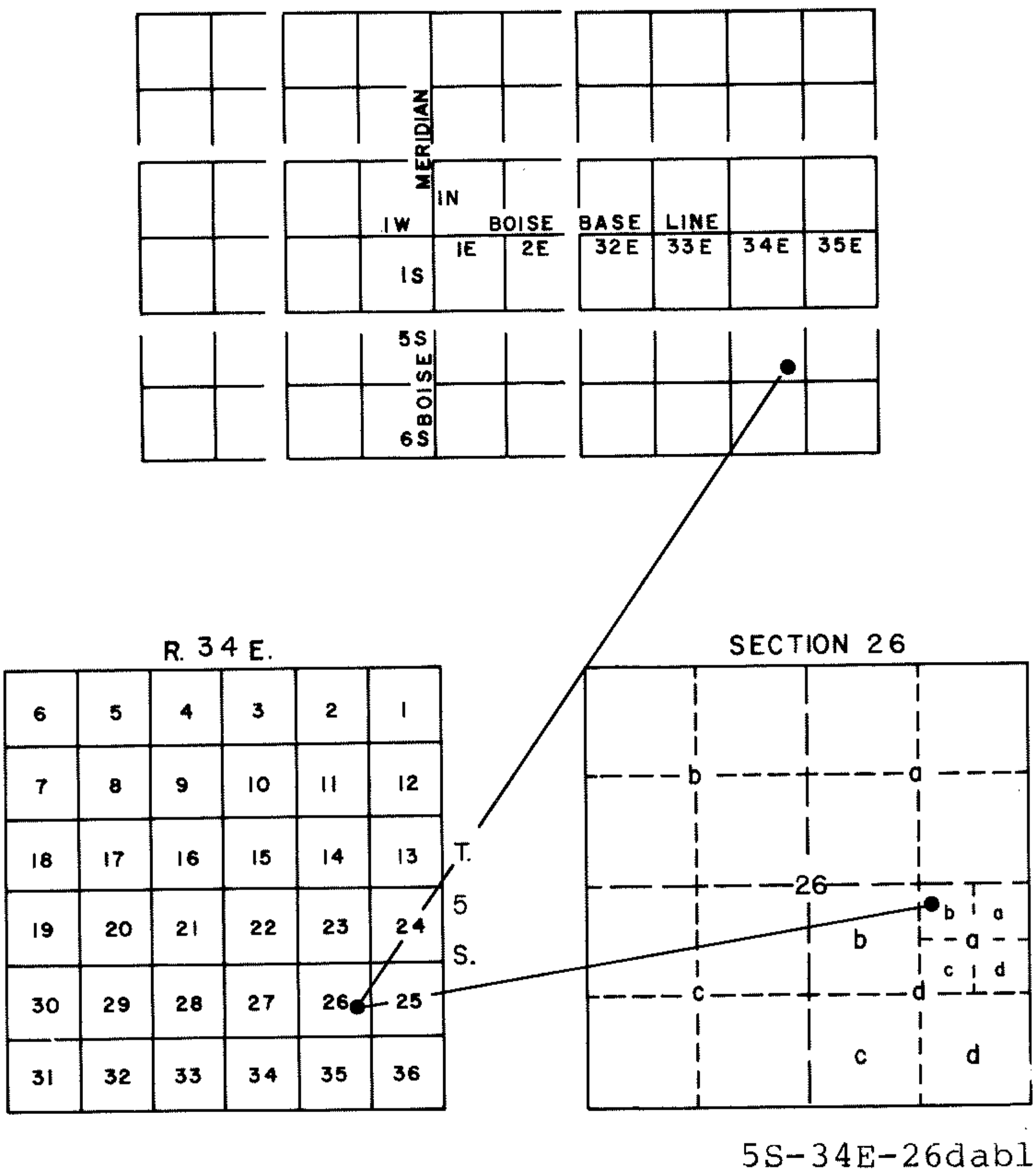


FIGURE 2. Diagram showing the well- and spring-numbering system. (Using well 5S-34E-26dabl)

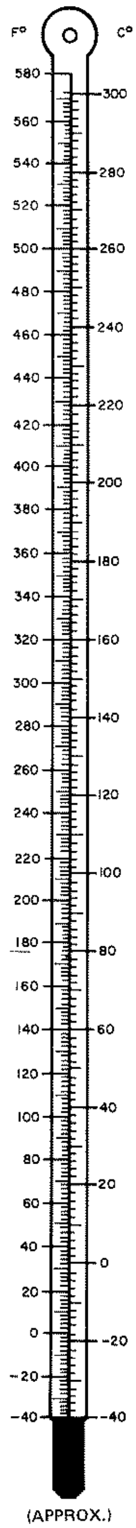


FIGURE 3. Diagram showing Celsius-Fahrenheit temperature relationships.

TABLE 1
CONVERSION FACTORS

To Convert from	To	Multiply by
inches	centimeters	2.540
feet	meters	0.305
yards	meters	0.914
miles	kilometers	1.609
sq miles	sq kilometers	2.589
gallons	liters	3.785
ounces	grams	28.349
centimeters	inches	0.394
meters	feet	3.281
meters	yards	1.094
kilometers	miles	0.621
sq kilometers	sq miles	0.386
liters	gallons	0.264
grams	ounces	0.035

GENERAL GEOLOGY

The Tyhee area, as defined in this report, can be subdivided into three separate and distinct geomorphic provinces (figure 4). The greater part of the area is considered to be part of the Snake River Plain, this being the flat terrain west of the Fort Hall Main Canal. The area immediately east of this canal rises bench-like as a somewhat dissected geomorphic pediment apron. The third and final geomorphic subdivision consists of the foothills of the Bannock Range along the very eastern margin of the study area. From these foothills major drainages such as Two and a Half Mile, Buffalo and Little Pocatello creeks debouche onto the pediment apron, dissecting it as they extend westward onto the Snake River Plain proper.

The most recent and up-to-date geologic study in the region including the Tyhee area is a 1976 report by D.E. Trimble on the "Geology of the Michaud and Pocatello Quadrangles, Bannock and Power Counties, Idaho," USGS Bulletin 1400. His mapping indicates that the surficial geology of the Tyhee area consists primarily of Quaternary deposits, some associated with Pleistocene events such as the Lake Bonneville overflow, and Pliocene-Pleistocene volcanics associated with early Snake River Plain development. The geology is summarized in terms of surface stratigraphic and structural relationships.

Stratigraphy

Starlight Formation - The Starlight Formation, as defined by Trimble, is composed primarily of bedded rhyolite

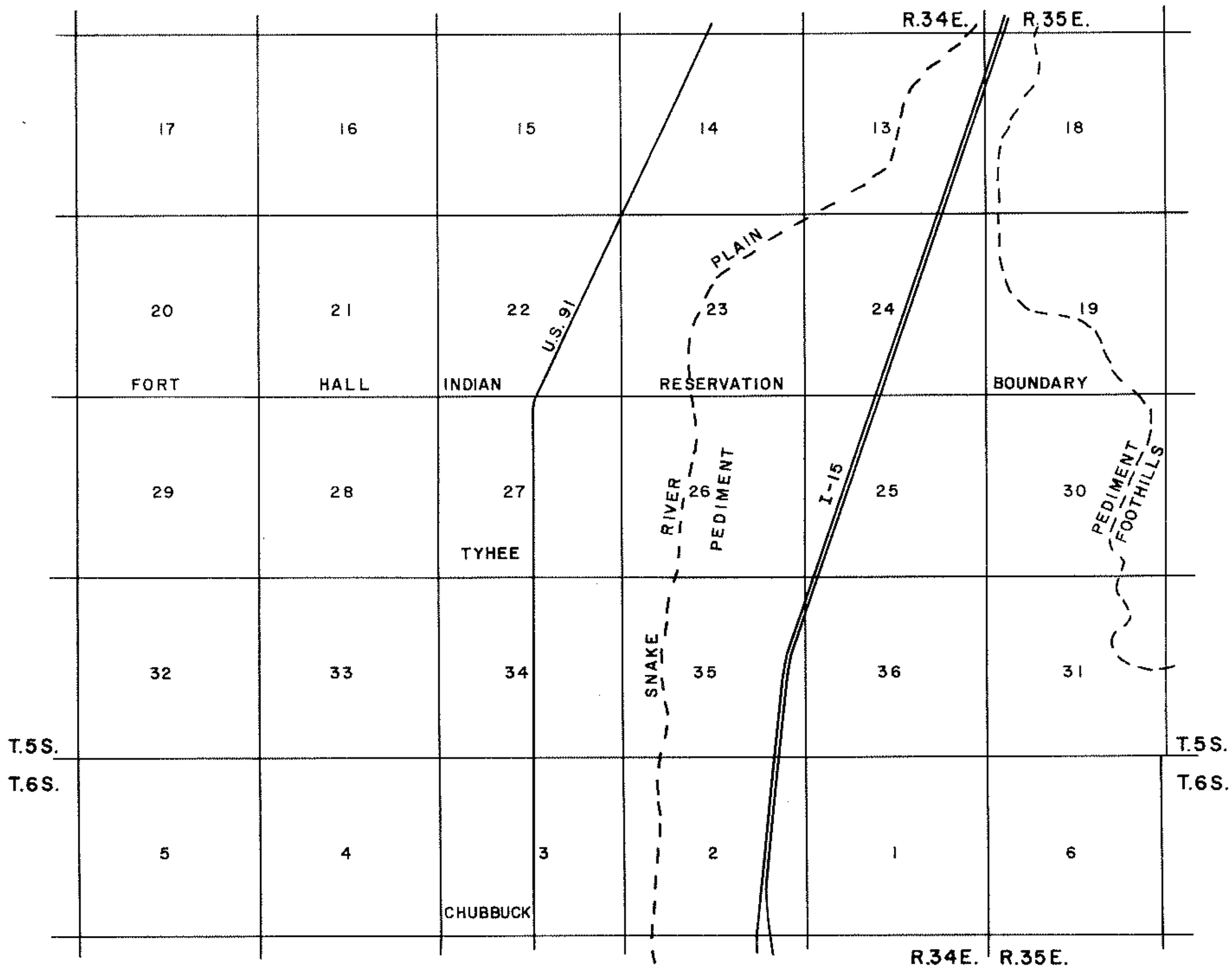


FIGURE 4. Diagram showing geomorphic provinces of the Tyhee area.

tuffs in these locations adjacent to the Snake River Plain. These materials tend to fill intermontane valleys and lap upon Paleozoic and older rocks of the mountains, in this case the Bannock Range east of the study area. Based on fossil faunas it has been dated as Early to Middle Pliocene. Outcrops of the Starlight Formation occur throughout the foothills province of the study area where they become responsible for the foothills type of topography present. These deposits in turn overlie sporadic outcrops of Paleozoic and Precambrian units of the Bannock Range east of the Tyhee area, thus masking the main range front boundary.

High Level Basalts and Rhyolites - For lack of definite formation names, these units are termed High Level Basalts and Rhyolites based on their manner of occurrence. Trimble discusses the basalts in association with lesser andesite porphyry masses and describes them as dark, dense, and fine-grained containing 55-60 percent plagioclase and 30-40 percent pryoxene with 10 percent olivine not uncommon locally. Some basalt outcrops are described as highly porphyritic and interpreted as vent deposits in the north central part of the Pocatello quadrangle where they appear to be localized along the trace of a minor northeast trending fault. In the study area these basalts are present as high level erosional remnants overlying Starlight tuffs in the foothills where they are in turn overlain occasionally by older pediment gravels and loess. These basalts are similar to and considered equivalent to high level basalt flows found in the Lava Hot Springs area as similar interbeds between ash flow tuffs and older Tertiary(?) gravels. These basalts are considered to be older than the typical Snake River Plain basalts, i.e., Lower Pleistocene - Upper Pliocene (Corbett, 1978). Minor exposures of these basalts also occur within or along the flanks of stream gullies that dissect the pediment province of the study area.

Northeast of Two and a Half Mile Creek, at the very north end of the area's foothill province, outcrops of older high level rhyolites are present. These also overlie the Starlight Formation and are overlain by loess. This rhyolite forms large hills and differs from Starlight tuffs primarily by their flow banded nature and the presence of basal breccia and perlitic obsidian horizons. They appear to be time equivalent to High Level Basalts and may in fact be genetically related as they also tend to appear as fault controlled vent-type volcanics that are post-Starlight but pre- or early Snake River Plain development.

Pediment Gravels - Minor exposures of pediment gravels occur overlying High Level Basalts of the foothills and along dissected gullies of the pediment province of the Tyhee area. Although these gravels outcrop more extensively in nearby Pocatello Creek and Portneuf River areas as bench deposits, they are more obscured in the Tyhee area by overlying loess. Yet their presence suggests a similar origin and depositional pattern as coarse alluvial deposits and mantling rubble aprons originating from erosion of adjacent mountains. These deposits rest on pediment surfaces cut on Tertiary rocks, particularly the Starlight Formation. They also vary from fanglomerates to alluvial aprons to alluvial stream deposits along major Pleistocene stream courses. All are presently graded to a level much higher than present base level and considered to be of Pleistocene age. In the Tyhee area these gravels are encountered at relatively shallow 25-30 meters (m) depths in wells within the pediment province east of the Fort Hall Main Canal and probably are much more extensive than outcrops suggest. As range front deposits, they are composed of boulders and pebbles of nearby Paleozoic and Precambrian units, particularly quartzites. These deposits also severely mask range front boundaries and similarly the eastern margin of the Snake River Plain. Thicknesses in the study area are generally unknown, but have been reported as reaching 38 m in nearby Pocatello Creek where they rest on Starlight tuffs. Exposures of these gravels in the Tyhee area are considered to be outside the main downwarp underlain by Snake River Plain basalts.

Michaud Gravels - Extensive surficially exposed gravels consisting primarily of quartzite and basalt lithologies covers much of the western half of the Tyhee project area. These gravels occur as lobate distributary deposits extending generally northwestward onto the Snake River Plain from the mouth of the Portneuf River Valley. They are extremely coarse with boulders present ranging in size up to 1 m in diameter in the Tyhee area, but with decreasing coarseness in the northwest direction. Trimble has contoured maximum particle sizes on his Pocatello Quadrangle map and the evolving pattern suggests three major distributary flows; one is north-northwest through the project area, another is northwest corresponding closely to the present Portneuf River channel, and a third is more westerly toward the Pocatello airport. The Michaud gravels are obviously younger than the Portneuf Basalt clasts contained within and are generally considered to have been deposited by water from pluvial Lake Bonneville discharging onto the Snake River Plain approximately 30,000 years ago (Late Pleistocene).

In the very southwest corner of the Tyhee study area local wells have penetrated 45-60 m of these deposits overlying Snake River Plain basalts.

Older Alluvium - Alluvial deposits younger than Upper Pleistocene Michaud gravels and yet older than recent or

Holocene alluvium occur in the Tyhee area particularly as a band extending northward through the middle of the area along the present path of the Union Pacific Railroad tracks. Other more extensive exposures occur along the Tyhee wasteway and in the northwest corner of the project area. These deposits thus tend to floor a channel and distributary system extending northward from the Pocatello area across the Tyhee area where it is composed principally of silty deposits up to 8 m thick.

Loess - Light-tan, poorly indurated, well sorted eolian silts containing up to 20 percent calcium carbonate mantles the pediment gravels and older rocks of the Pocatello Bench or pediment province of the Tyhee area. This loess is locally 60 m or more thick at lower elevations, thinning eastward toward the foothills at higher elevations. Gullies cutting the loess tend to be somewhat flat-floored with steep to vertical sides. Interwaterway areas are relatively flat and well drained. The Pocatello Bench as a whole is almost entirely underlain by these eolian silts and tends to slope gently westward toward the Snake River Plain in a slightly concave manner.

Younger Alluvium - Covering the floors of the present drainage channels along which the Fort Hall Main Canal was constructed is a band of younger Holocene alluvium comprised mainly of fine sands and silts. Mixing with these channel deposits are alluvial fan materials where intermittent pediment streams emerge onto the Snake River Plain from the Pocatello Bench at its step-like junction with lower lying terrain. These deposits are of little significance other than marking areas presently active in terms of today's stream activity.

Structure

Very little can be said structurally about the Tyhee area except by inference. For this reason, gravity and magnetic surveys were undertaken for the Tyhee area in order to provide a clearer and more detailed understanding of the area's subsurface structural configuration.

Regionally the Tyhee area is marginal to two major structural provinces, the Snake River Plain Downwarp and adjacent overthrust belt structures upon which has been superposed the horst-graben character of the Basin and Range Province. Regional studies (Corbett, 1978) tend to suggest that severe Basin and Range faulting during Mid-Cenozoic has resulted from upwarp and extension of a large portion of southeastern Idaho. The present day topography of adjacent Snake River Plain borderlands reflects this event. Similarly, regional studies tend to show strong correlation between Basin and Range faulting and local hot spring sites throughout southeast Idaho. Such a correlation is also strongly suspected for reported hot waters of the Tyhee area. The subsurface structure of the Tyhee area is therefore important in any geothermal resource assessment.

The mountain blocks making up the Bannock Range, and the intermontane valley flanking the Pocatello area's part of it (the Portneuf Valley), were formed by Basin and Range faulting. Much of this faulting occurred prior to deposition of Middle Pliocene silicic volcanics (Starlight Formation) that partly filled intermontane valleys. Although faulting cannot be accurately dated it does appear to have been complete by early Snake River Plain development. Movements along Basin and Range faults have offset and/or disturbed pediment gravels, tuffs, and older basalts correlative to those reported present in the Tyhee area in other ranges and valleys nearby, particularly in the Lava Hot Springs area (Corbett, 1978). Such offsets are minor in comparison to total displacements measured for major Basin and Range block faults of the region (100s of m). However, these offsets suggest that Basin and Range faulting continued into Pliocene time.

Several lines of evidence tend to imply that the Snake River Plain formed as a large graben structure. Mountains both north and south of the Plain appear to be truncated by faults that bound the Plain. These faults also trend distinctly different than those attributed to Basin and Range development. At the same time some range boundary faults are known which extend into the Snake River Plain, thus it appears there has been some overlap between Snake River Plain formation and Basin and Range faulting in the region. A complete interplay of structural relationships should therefore be expected in areas marginal to or common to both tectonic provinces. Generally, however, Snake River Plain development is considered to have occurred post-Basin and Range or at least during later stages. Because the region is still undergoing extension there is no doubt that continued rejuvenation movements may still take place along both older Basin and Range faults as well as more recent Snake River Plain boundary faults. This is especially significant in terms of possible geothermal potential for the Tyhee area.

Best estimates of the age of Basin and Range structures in the region is that it is pre-Starlight Formation (i.e., pre-Pliocene) and post-Cretaceous overthrust development. Snake River Plain development also appears to have begun no later than Middle Pliocene for the Starlight Formation may be representative of early silicic volcanic phases attributed to or associated with Snake River Plain development.

The transition from Basin and Range faulting and downwarping of the Snake River Plain appears to be tectonically related and the complete stratigraphic relationships existing between the Starlight Formation, High Level Basalts and Rhyolites, and Pediment Gravels discussed for the Tyhee area may be indicative of this transition.

The only major structural feature shown on Trimble's Pocatello Quadrangle map for the Tyhee area (within project boundaries) is an inferred Snake River Plain boundary fault whose trend extends northeast across the Pocatello Bench and into foothill volcanics at the northeast corner of the project area. Based on independent interpretation of stratigraphic relationships it seems preferable to place outcrops of High Level Basalts and Rhyolites, and possibly Pediment Gravels as well, outside of the main Snake River Plain; it is felt that Trimble has inferred the Snake River Plain boundary as being too far east by 1 to 2 km or more. It is also quite probable that the Snake River Plain boundary consists of a zone of fault dislocations as wide as 2-4 km extending as a band marginal to the Plain as a whole. As discussed later, it appears that geophysical evidence supports this interpretation.

Trimble provides evidence for the subsurface extent of Snake River Plain basalts in the Tyhee area. Nearest outcrops occur near American Falls to the west, and in the Ferry Butte area to the north. Generally, however, geophysical evidence suggests that these basalts are not present in the subsurface as far east as originally felt by most individuals; they extend eastward to a point 1 to 2 km west of the obvious geomorphic margin of the Snake River Plain as determined topographically. There is little doubt that Trimble's interpretation of some of the High Level Basalts and Rhyolites is correct, that they are indeed fault related and mark surface traces of deeper faults. To this extent the Snake River Plain boundary has some surface expression in and near the Tyhee area.

GRAVITY

FIELD WORK

The gravity survey of the Tyhee area was begun in the fall of 1978 with field work completed in March, 1979. A base station was established at the intersection of Tyhee Road and the Union Pacific Railroad; from this point gravity readings were taken with a direct reading Worden Gravimeter over a 72 sq km area. Generally a grid pattern consisting of both north-south and east-west traverses was set up with readings made at 0.80 km intervals. These traverses followed both section and quarter section lines.

Elevation control for the gravity survey was provided by local bench marks and spot elevations taken from USGS topographic maps of 1/24,000 scale.

During any given day's work base station readings were reread at 1-2 hour intervals. These were plotted as time-dial reading drift curves for later use in correcting for daily fluctuations caused by atmospheric effects.

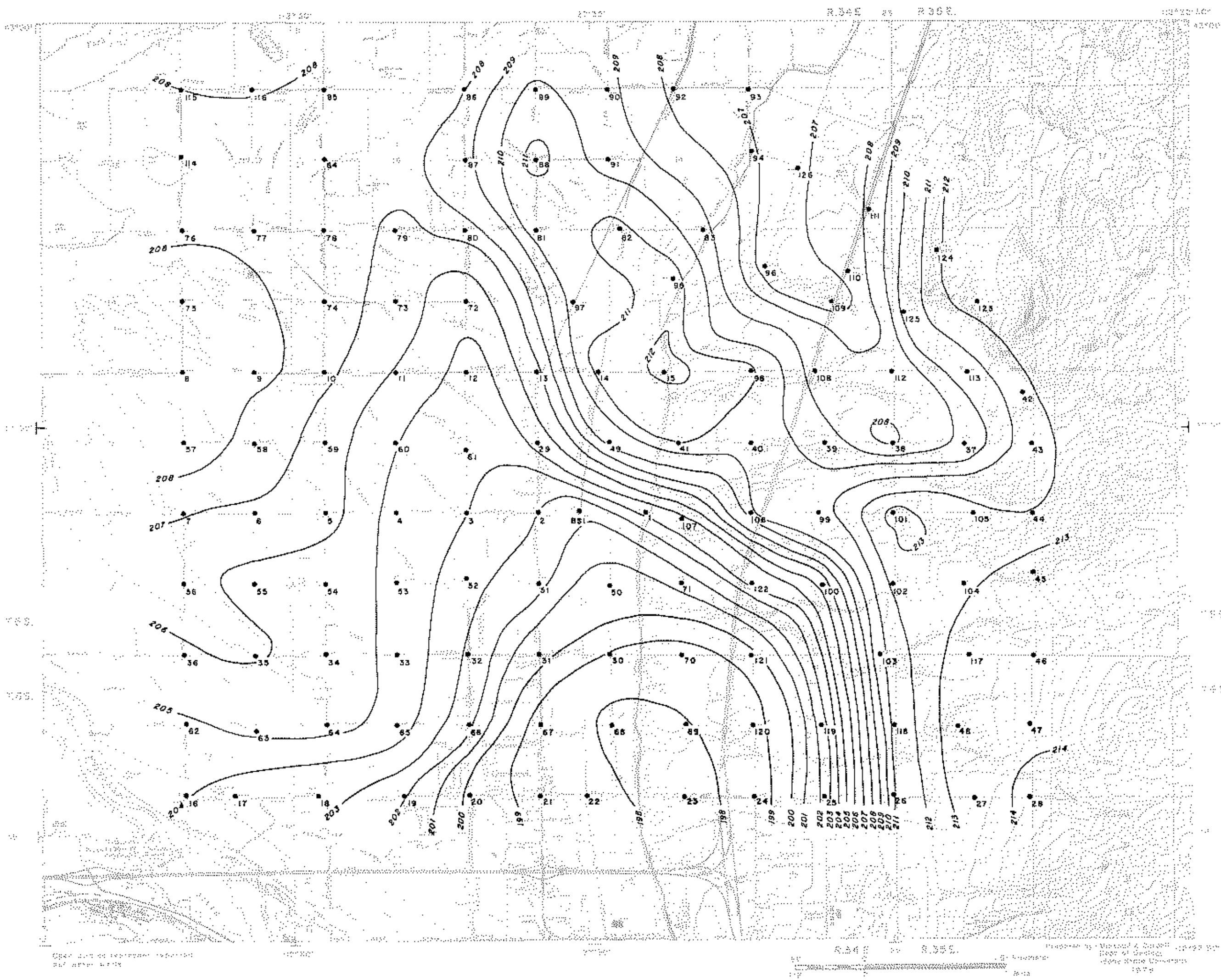
DATA REDUCTION AND CORRECTIONS

Direct gravimeter dial readings for all stations have been corrected and/or reduced to provide observed Bouguer gravity values which in turn were tabulated and contoured. Data reduction included corrections for daily drift and reduction to a common elevation of 1281 m above sea level and for a latitude of $43^{\circ}00'$. An additional terrain correction was also applied according to standard procedure using a uniform density of 2 grams per cubic centimeter (gm/cm^3), this value being an average determined for surficial materials covering most of the survey area. All field observed data corrections, and final Bouguer values, are tabulated in the Appendix, table 1.

A contoured gravity map with full milligal contour intervals has been prepared as figure 5. In addition two observed gravity profiles, with attendant topographic profile, were plotted along east-west traverses along Ballard and Siphon roads and their extensions eastward. These are presented as figure 6.

Although the gravity data used in this study are observed gravity rather than absolute, the patterns of gravity highs and lows etc., are essentially the same. The main exception is simply that all data is positive with larger

FIGURE 5. Gravity map showing thermal well locations in the Tyhee area.



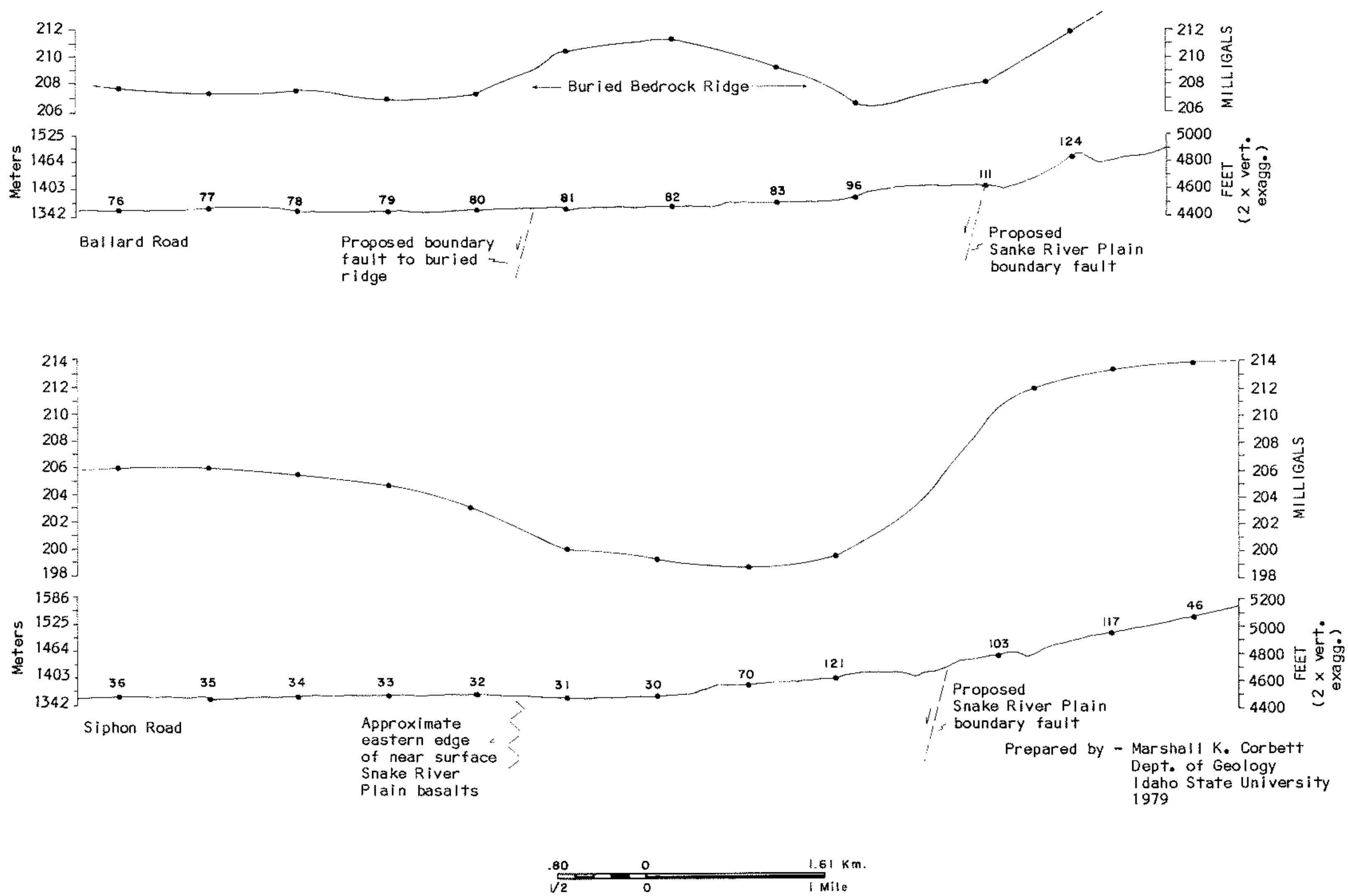


FIGURE 6. Topography and observed gravity profiles in the Tyhee area.

contour values outlining gravity highs and low contour values being associated with gravity lows.

GEOLOGIC INTERPRETATION

Contoured observed Bouguer gravity (figure 5) and topographic-gravity profiles (figure 6) form the basis for the following geologic interpretations. Several primary gravity patterns emerge which have geologic significance. First, two main gravity lows are present, one centered just east of Chubbuck, the other a more elongate low extending northwestward from the mouth of Two and a Half Mile Canyon in the northeast corner of the study area. Separating these lows is a ridge-lake gravity high of northwest trend which extends into the Snake River Plain from the adjacent Bannock Range. Both patterns appear abnormal and have no surface topographic expression, thus they are interpreted as indicative of subsurface structural configurations.

The broad gravity high along the western border of the study area appears to reflect the presence of Snake River Plain basalts of increased thickness overlain by Michaud gravels. This broad high breaks abruptly, but not greatly, into the Chubbuck "low" in the southern part of the area and laps without change against the gravity ridge in the northern part of the area.

An interesting aspect of the gravity data is the manner in which contours around the Chubbuck "low" tend to portray a distributary pattern both westward and northwestward. These contours tend to parallel Trimble's basalt boulder size contours on his published geologic map of the area (Trimble, 1976, figure 5). Gravity values tend to rise along these distributaries as basalt boulder sizes decrease, thus reflecting the depositional pattern of Michaud gravels of the Lake Bonneville overflow. The Chubbuck "low" is, therefore, partly interpreted as being erosional, i.e. as a basinal area excavated by streams debouching onto the Snake River Plain which was later back-filled with low density sedimentary materials. A similar interpretation is being given to the Two and Half Mile "low", it probably being in part erosional with similar back-filling of sediments issuing from the canyon.

Complicating this simple interpretation for the major gravity lows, however, is the abruptness in which gravity values rise eastward from both lows. As shown in figure 5 and figure 6 a steep north-south linear trend is portrayed by this abrupt rise in gravity. It is particularly evident east of Chubbuck, but has noticeable northward extension in spite of being interrupted in the area where I-15 crosses the northwestward trending gravity ridge. The interpretation being given to this north-south trend is that of a major normal fault, dipping westward, thus separating bedrock of the Bannock Range to the east from similar materials overlain by unconsolidated sediments on the downdropped side.

Figures 5 and 6 also reveal the presence of a similar linear abrupt break in gravity values flanking the ridge-like gravity high within the near central portion of the study area. It too is being interpreted as being a normal fault, southwest side down, but of somewhat less magnitude. As shown by open circles on figure 5, reported hot waters in local wells of the region tend to plot along this trend, particularly near its intersection with the stronger north-south trend.

In summary, it appears from gravity data alone that the Tyhee area can best be described as having a major subsurface structural high (tilt block?) extending plainward as an extension of the Bannock Range, this ridge in turn having been downfaulted along an north-south fault which appears as the dominant Snake River Plain boundary structure present. The non-coincident but closely related nature of this trend with Trimble's inferred Snake River Plain boundary fault should be noted.

MAGNETICS

FIELD WORK

Magnetic measurements for the Tyhee area were made during late spring of 1979, these being made as close to the prior grid system established for the gravity survey as possible. A direct reading proton magnetometer of .01 gamma sensitivity was used, and extreme care was taken to select stations a minimum of 60-90 m from all visible overhead power lines, phone lines or fences. This care was taken to avoid magnetic effects of manmade structures. As with gravity, a base station was established, it being located near the intersection of Tyhee Road and Hi-Line Road. Daily readings at 1-2 hour intervals were made at this base station and daily variations recorded as time-gamma drift curves.

DATA REDUCTION AND CORRECTIONS

The only necessary correction to be made in order to obtain absolute surface recorded magnetic intensity readings is the adjustment of initial readings for daily magnetic fluctuations. This was done by simply correcting all recorded data based on magnetic drift curves, these in turn plotted to a single datum (see Appendix, table 1).

Magnetic values were contoured (figure 7) using contour intervals of 100 gammas and inferred dashed contours of 50 gammas. Figure 7 is a total magnetic intensity map of the Tyhee area.

GEOLOGIC INTERPRETATION

As noted on figure 7, two general magnetic patterns are revealed. Basically, a major part of the western half of the Tyhee area, west of a line 0.4 km west and parallel to US91, is interpreted as being underlain at relatively shallow (30-60 m) depths by basalts of the Snake River Plain. The busy, somewhat sporadic pattern of local magnetic highs and lows ranging 500-700 gammas is not unusual for basaltic materials due to variations in Fe oxidation states in such substances. The line referred to is thus interpreted as being the eastern limit for Snake River Plain basalts.

Elsewhere with minor exceptions, the magnetic pattern is somewhat more subdued with local variations closer to 100 gammas. This reflects the absence of highly magnetic

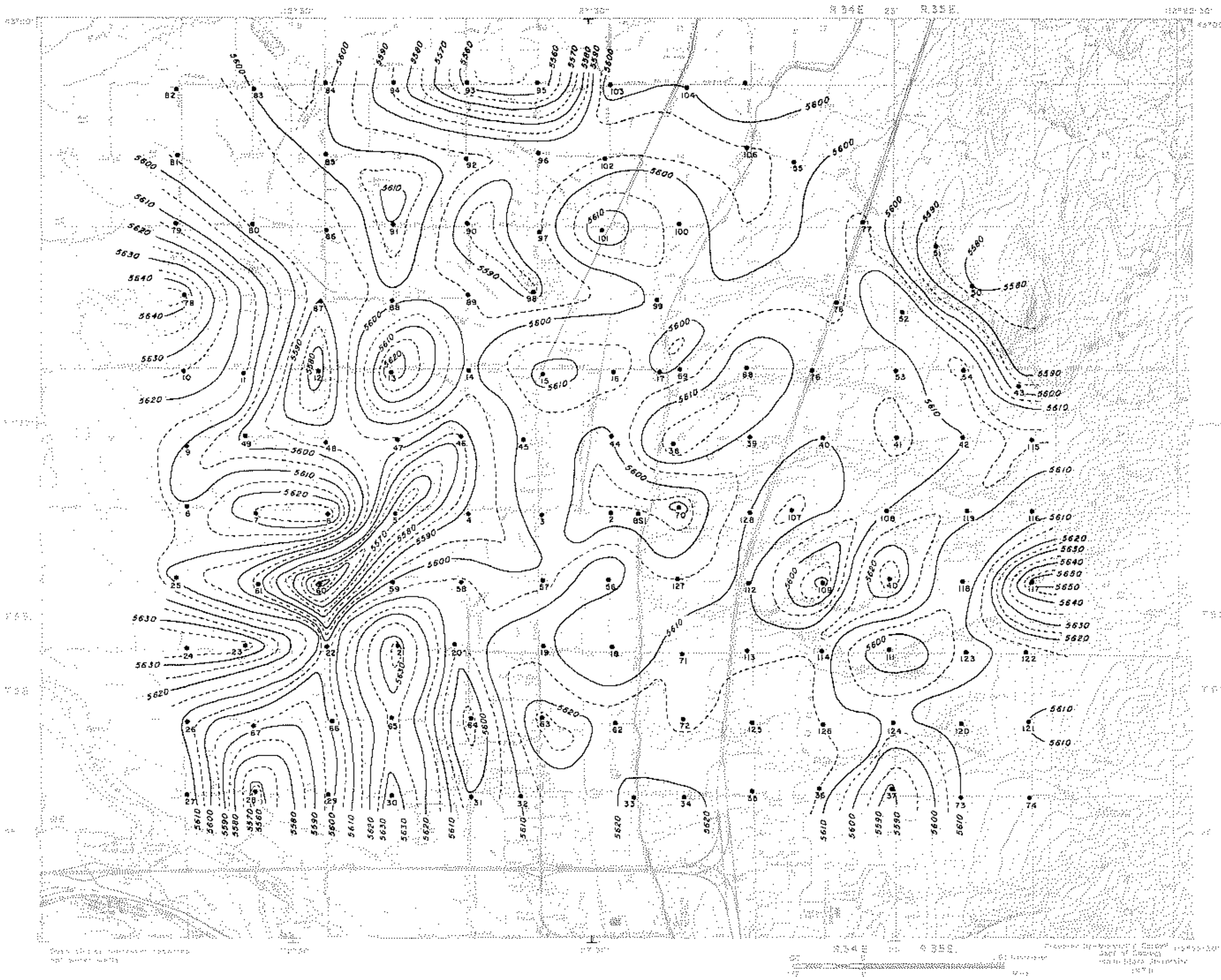


FIGURE 7. Magnetic map showing thermal well locations in the Tyhee area.

materials and more closely approximates sediments, sedimentary rocks and/or silicic volcanics.

One exception to the patterns just described is the existence of a 200-300 gamma intensity range zone within the pediment-foothill region east of I-15 and in a band extending northwest that is contiguous with the previously described gravity ridge. Possibly this somewhat more varied pattern is associated with volcanics and/or consolidated sedimentary rocks rather than unconsolidated sediments. Interestingly the western margin of the 200-300 gamma zone coincides closely to faults based on gravity interpretation.

A second exception is the manner in which a zone of lowered magnetic intensity extends across the basalt underlain portion of the Tyhee area in the northwest part of the study area. This low magnetic band closely corresponds to the Tyhee wasteway and is interpreted as possibly reflecting channeling, thus thinning or removal, of basalts.

Other local variations also occur. The extreme magnetic high at the east boundary of the study area is easily explained. Station 117 was an exposed outcrop of older high level basalt. The slight magnetic ridge extending along the present channel of Two and a Half Mile Creek corresponds to a gravity low. At first glance this may seem anomalous, however, this drainage extends several miles up canyon into the Bannock Range to a locale in which igneous plutonic rocks occur. Thus the sediments transported may be of higher magnetic character.

In the very northeastern corner of the study area is a major magnetic low corresponding exactly to foothill areas where outcrops of silicic perlitic rhyolite are exposed.

In summary, the magnetic patterns closely approximate or duplicate gravity patterns and serve as reinforcement for gravity interpretations. Yet, a distinction between structural variations and compositional variations can also be made from magnetics of the Tyhee area.

SUMMARY AND CONCLUSIONS

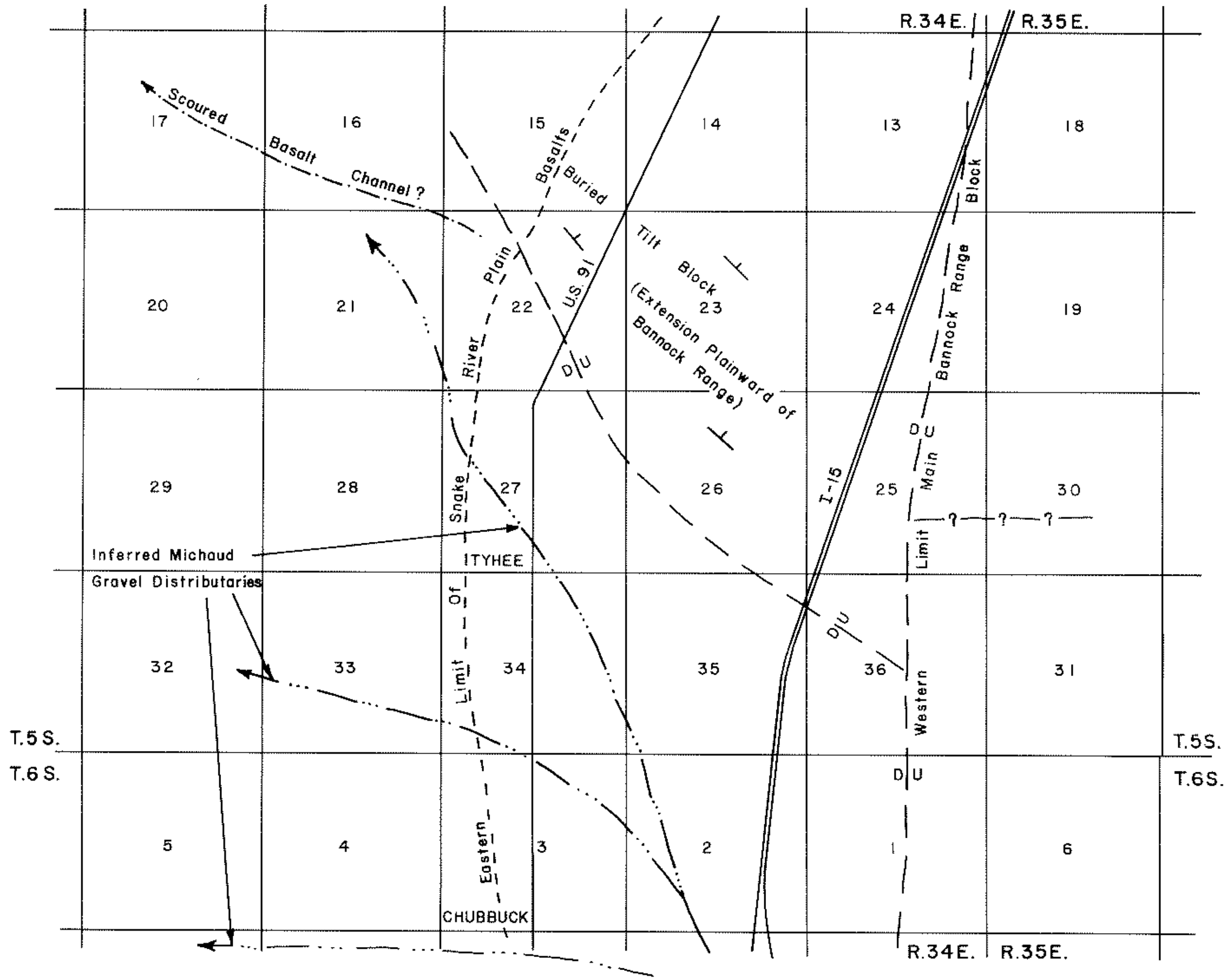
Several lines of evidence can now be used to focus on the subsurface geology of the Tyhee area in order to evaluate its potential for further exploratory work. Taken together the gravity and magnetic data derived from these surveys tend to reveal what has been interpreted as the primary structural configurations present and they provide some additional information concerning the area's probable compositional character. When added to surface geology and what is evident from regional structure, a useful model evolves (see figure 8).

The Tyhee area is marginal to the Snake River Plain and thus sets astraddle the main boundary separating the Plain from the adjacent Bannock Range block. The nature of this boundary closely resembles a compound truncation of Basin and Range structure along a major north-south normal fault with subsidiary northwest normal faulting creating lesser variably downthrown blocks which extend plainward without strong surface expression. These structures appear to be transitional between typical Basin and Range development and later establishment of the Snake River Plain downwarp.

Reported hot waters of the area appear to be both spatially and genetically related to the major faults present, particularly with their intersection. Recurrent movements along them is believed to generate permeable zones for water circulation and is thought to be the most plausible mechanism controlling hot water occurrence, a condition not unlike that for all of southeast Idaho. An analogy might be made between the Tyhee area and the Lava Hot Springs or Heise Hot Springs areas. All seem to have similar geologic characteristics structurally and stratigraphically.

Prior to undertaking a geothermal exploratory hole in order to develop the area's geothermal potential, some additional studies are recommended. Although the results of magnetic and gravity surveys provide important clues to the character of subsurface structures, there is a need for more accurate determination of their locations. In particular, the north-south and northwest fault trends should be precisely known, their attitude measured, and perhaps some knowledge of magnitude of displacement obtained. Additional data pertaining to the geographic location and depth of focus of hot water generation would prove invaluable. Although the existence of a target has been implied, its precise location is unknown.

FIGURE 8. Diagram depicting subsurface structure.



It is recommended that future development work be carried out in two stages. Stage 1 would involve seismic refraction or high resolution reflection profiles along lines perpendicular to the two main fault structures inferred from present work. Stage 2 might be the drilling of a series of shallow test or monitoring holes centered around the area of known hot water. These would prove useful as structural and stratigraphic tests and also be available for collection of badly needed thermal and hydrologic data. Once completed, these additional studies might be followed with one or more deep exploratory holes. It should be emphasized that without some idea of the thermal configuration of underground waters, deep drilling might prove wasteful.

HYDROLOGY

WELL LOG DATA

The occurrence of groundwater in the north Pocatello, Chubbuck and Tyhee areas is closely related to the geology and is as varied as the three described geomorphic provinces.

Geologic cross sections (figures 9 & 10) derived from water well drillers logs (see figure 11 for cross section locations) shows the depth of the water table to be greater in the areas of high relief (eastern edge of the study area) than it is at the lower elevations of the Snake River Plain proper; however, locally water levels change significantly due to local differences in the continuity and permeability of the water bearing materials as well as the influence of the local structure.

Water levels in the bench area are found to vary from 60-90 m below land surface. The piezometric levels in the area appear to be slightly artesian with only one well (5S-34E-24dabl) known to be flowing at approximately 15 l/min. This well has a surface temperature of 41°C.

The major water producing zones in the bench area (from well logs) appear to be the more permeable alluival sand and gravel deposits and ancient colluvial rubble aprons including the "High Level Basalts" when fractured and found below the water table.

The Snake Plain alluvium consists of interbedded clay, sand and gravel. Water levels in the Plain are varied but usually no more than 15 m below land surface. The lateral continuity of the major water producing zones within the Plain is questionable as sufficient data are not available to make a detailed analysis. A generalized stratigraphic section for the Tyhee area is shown in figure 12.

Relatively little is known about the structure of the area as the deposition of the sediments has masked much of any surface expression. Cross sections indicate north to northeast trending normal faulting along the Plain margin as well as some northwest faulting. These trends are substantiated by the Landsat imagery interpretations (this report) and gravity and magnetic studies of the area. Age relations of the faulting are undetermined presently but the north to northeast trending normal faults along the plain margin are thought to be the younger (figure 8).

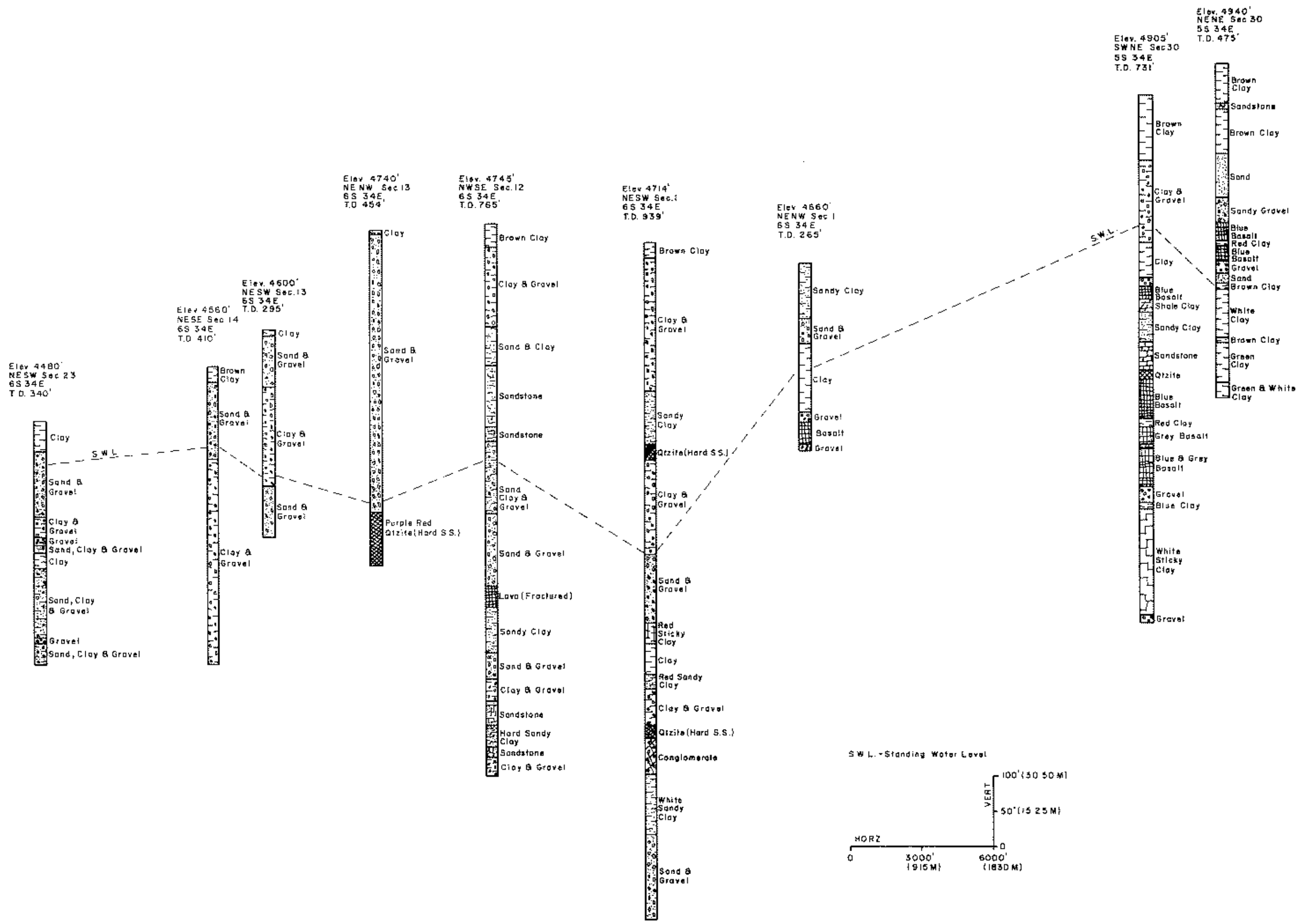
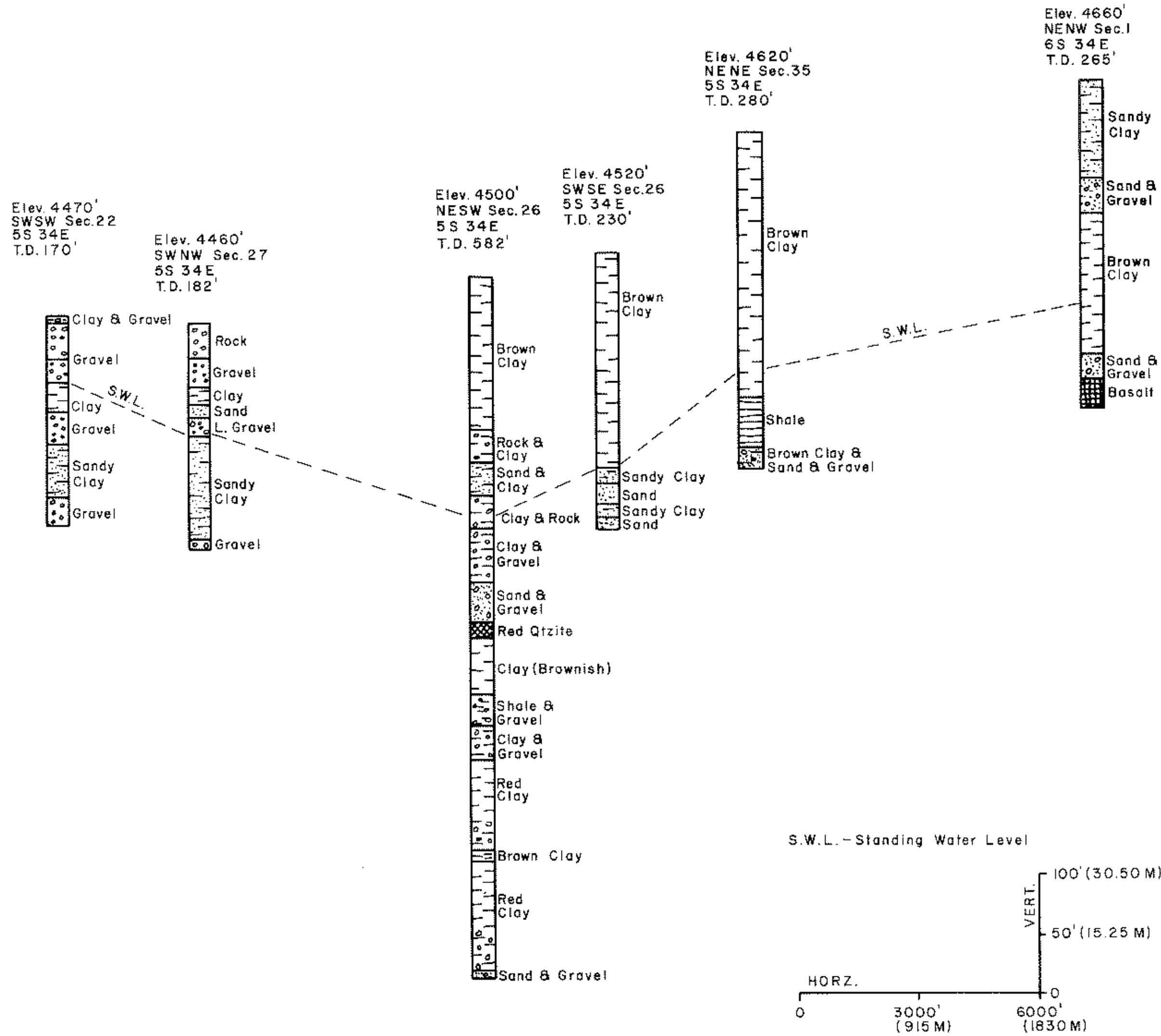


FIGURE 9. North-south geologic cross section of Tyhee area. (Anderson, 1980)

FIGURE 10. East-west geologic cross section of Tyhee area.
(From drillers logs)



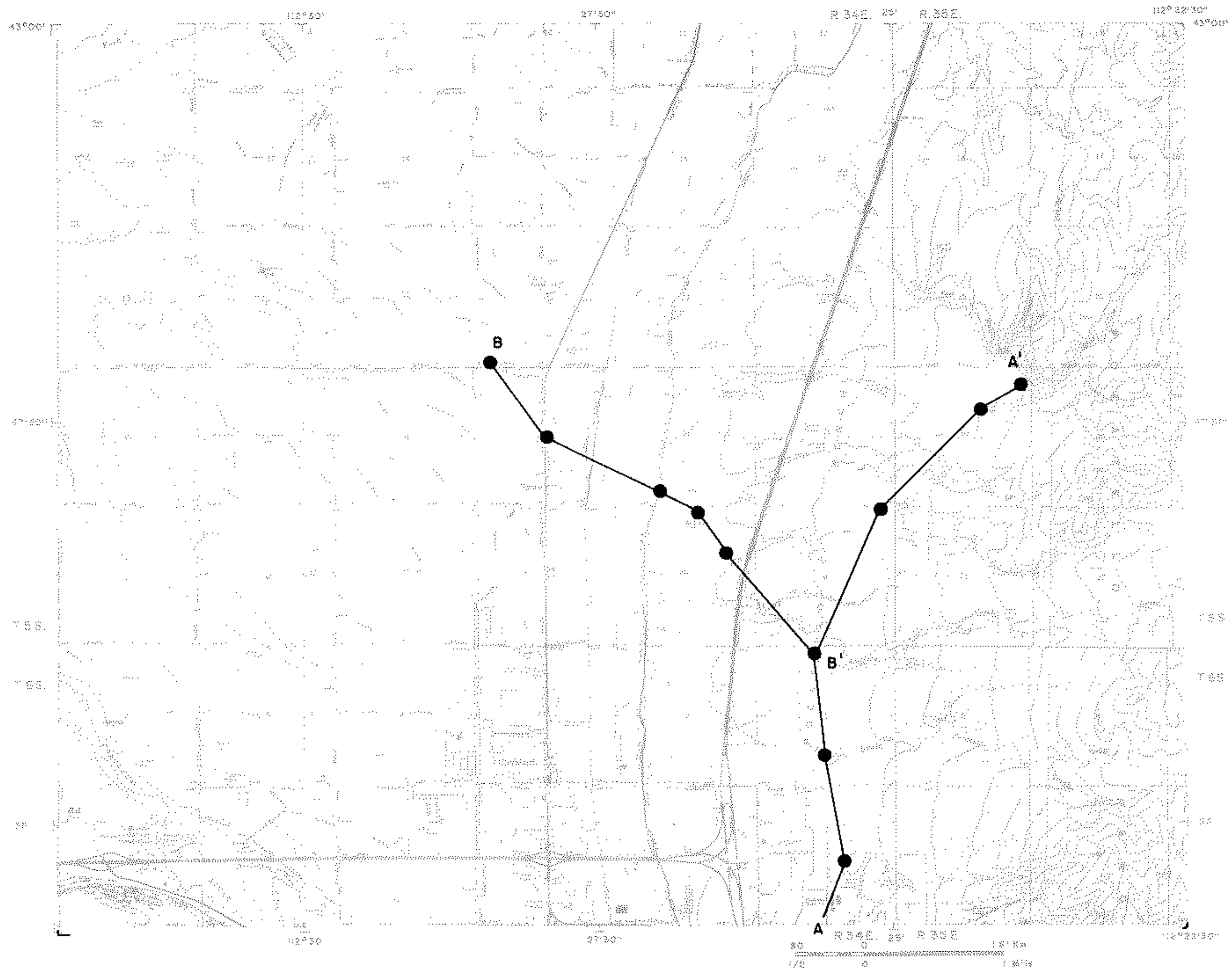
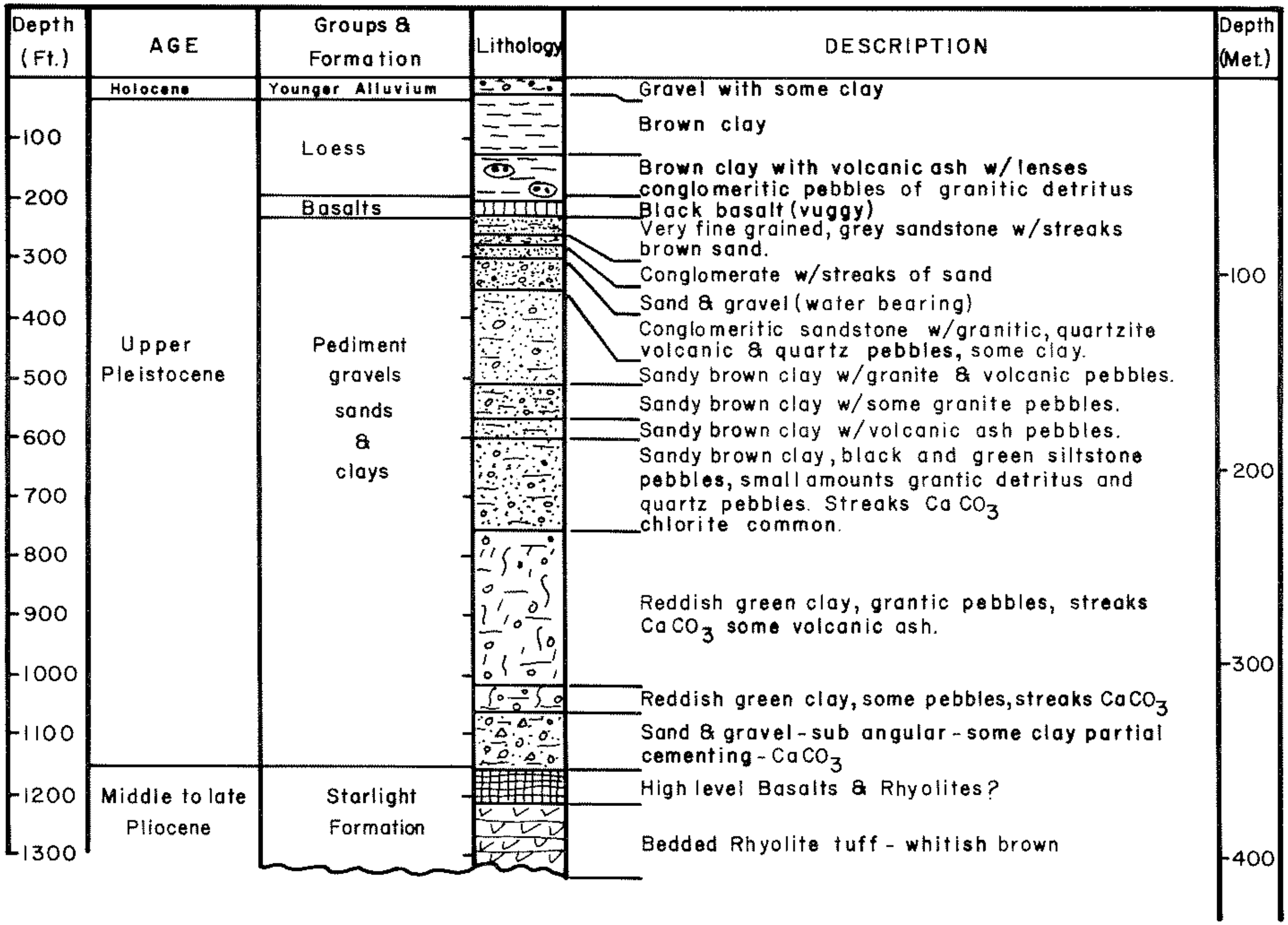


FIGURE 11. Map showing locations of wells for stratigraphic cross sections.

FIGURE 12. Typical stratigraphic section in the Tyhee Bench area. (Anderson, 1979)



These fault systems seem to be the key to exploiting the warmer water. In the previously described flowing well, warm artesian water was encountered at a depth of 244 m. This well may have intersected one of these faults at depth.

Another well was recently drilled in Section 25cccl, T.5 S, R.34 E, by Energy Services, Inc. of Idaho Falls, in search of a resource to use in a future housing development for space heating. This well was drilled to a depth of 323 m. It was anticipated this well would intersect, at or near this depth, a northwest trending fault (dip about 75° to the northeast) that has been identified at the surface about 270 m to the south of the well site or possibly one of the northeast trending normal faults. Immediately after completion of this well it caved in at 220 m. To date, data is available for only the upper 220 m of the well. The current water level is 4.58 m below land surface, and it has a static level temperature of 14°C.

A well located about 10 m to the south of the previously described well is 85 m deep and its water level is 60 m below ground level. Water temperature in the well varies from 21°C at the static level to 24°C at the bottom of the well. Warmer water may be migrating into this well through a sand and gravel aquifer from fractures associated with the same northwest trending fault zone.

CONCLUSIONS AND RECOMMENDATIONS

It appears that warm water sufficient at least for space heating may be available in this area if the local structural control can be defined and tapped at depth. Further study should be initiated to delineate suspected structures and further define known structures to enable a possible resource to be found and used. Flow tests should be run on the known warm wells to determine if sufficient yield exists for sustained use and to determine if well interference will be a problem. Environmental considerations such as waste water discharge should be looked at prior to any development.

GEOCHEMICAL STUDY

THERMAL WATER CHEMISTRY

Thermal water occurrences near Tyhee are limited to a small area of about 31 sq km (12 sq mi). The hottest thermal water (41°C) comes from a well (5S-34E-26dabl) located near the center of the 31 sq km area. Other wells in the area are much cooler, with surface temperatures ranging from 12 to 28°C.

The hot well was drilled to a depth of 177.5 m in 1963 and is presently used for domestic heating and irrigation purposes. A drillers log is available for the first 177.5 m. The well has subsequently been deepened by 46 m. A former thermal spring has been reported (5S-34E-27dablS) near the Union Pacific Railroad tracks. It is now dry, so no sample or reliable temperature could be obtained therefrom. It is reported to have ceased flowing after the Hebgen Lake earthquake that shook the area in August 1959. Former flow was enough to provide a "bath-tub" for bathing. Kent Shiozowa, the owner, has stated that the temperature was between 25 to 35°C (Kunze, 1980, personal communication).

Wells which were pumping at the time well-site visits were made, were sampled and chemically analyzed during the early fall of 1979 (table 2). Several other wells exist in the area, but were not pumping during the sampling period. Reliable isotope samples could not be obtained due to lack of well head access ports in the area.

Data in table 3 indicate two distinct types of water are present in the Tyhee area. Higher temperature water (above 25°C) have higher concentrations of dissolved sodium (Na), potassium (K), sulfate (SO_4), and fluoride (F), than lower temperature waters. Silica, however, tends to be present in lower concentrations in the warmer water. The percent sodium (percent Na) and sodium absorption ratios (SAR) are higher for warmer water (typically 40-50 for percent Na and 2.9 - 3.8 for SAR) while cooler waters have percent Na less than 30 and SAR values less than 1.5.

Chemical water quality data are often displayed as vertical bar graphs using milliequivalents per liter as units. Figure 13 relates water quality to location. The figure shows an apparent water chemistry change from west to east across the area. Topographic and land use changes from west to east could mean that the water chemistry variability

TABLE 2

CHEMICAL ANALYSES OF THERMAL AND NONTHERMAL WATERS FROM THE TYHEE (NORTH POCATELLO) AREA

BANNOCK COUNTY, IDAHO

Spring or Well Identification Number and Name	Sample Collection Date	Measured Surface Temperature °C	Reported Well Depth below Land Surface (meters)	Discharge (l/min)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Phosphate (PO_4)	Chloride (Cl)	Flouride (F)	Nitrate (NO_3)	Boron (B)	Ammonia (NH_3)	Specific Conductance (field)	pH (field)	Total Dissolved Solids (TDS)	Hardness: Carbonate	Hardness: Non-Carbonate	Alkalinity as $CaCO_3$	Percent Sodium (%Na)	Sodium Absorption Ratio (SAR)	Cation-Anion Balance	Data Reference*	Reference Number (See Figs. 13 & 14)
SHOAL SUBDIVISION WELL 5S 34E 26dba1	6/20/79	26	72.	378.	38	93.0	39.00	176	25.00	425.	0.0	156.00	0.0	228.0	2.70	6.90	-	-	0	0.0	973	392.	44.	348.	47.4	3.9	-2.248	10	1
RICHARD JONES WELL 5S 34E 24acc1	6/19/79	19	64.	4542.	53	53.0	19.00	27	8.60	251.	0.0	32.00	0.0	35.0	0.37	0.82	-	-	536	7.9	352	210.	5.	206.	21.0	0.8	-1.764	10	2
GERALD JOHNSON WELL 5S 34E 25cbb	6/19/79	25	81.	30.	59	40.0	24.00	95	16.00	345.	0.0	72.00	0.0	67.0	1.50	0.67	-	-	871	7.6	544	198.	0.	283.	48.6	2.9	-3.469	10	3
SHOAL SUBDIVISION WELL 5S 34E 26dbd1	7/13/76	25	22.	0.	41	45.0	37.00	160	2.70	468.	0.0	100.00	0.0	100.0	2.50	0.0	-	-	1219	7.2	718	264.	0.	384.	56.5	4.3	-1.625	9	4
BERT HUTH WELL 5S 34E 26dba1	6/19/79	28	47.	378.	36	95.0	39.00	172	26.00	411.	0.0	157.00	0.0	240.0	2.70	7.00	-	-	1669	7.4	976	397.	61.	337.	46.5	3.8	-2.829	10	5
H RUPP & M JENSEN WELL 5S 34E 35bad1	6/19/79	17	0.	757.	47	70.0	29.00	58	9.90	329.	0.0	61.00	0.0	69.0	0.70	5.10	-	-	846	7.6	511	294.	24.	270.	29.2	1.5	-0.550	10	6
RICHARD JONES WELL 5S 35E 30aca1	6/19/79	15	0.	30.	42	60.0	29.00	25	6.60	317.	0.0	19.00	0.0	50.0	0.48	0.66	-	-	632	7.7	388	269.	9.	260.	16.4	0.7	-2.981	10	7
HARRY HARDT 6S 34E 1cda1	6/19/79	23	0.	757.	48	70.0	23.00	28	8.50	273.	0.0	28.00	0.0	57.0	0.20	0.55	-	-	661	7.5	397	269.	46.	224.	17.9	0.7	0.974	10	8
ROBERT BROWN WELL 5S 34E 26dab1	7/27/72	41	177.	57.	20	70.0	25.00	150	21.00	478.	0.0	95.00	0.0	87.0	3.20	0.02	-	-	11169	7.7	706	277.	0.	392.	51.7	3.9	0.700	3	9

*DATA REFERENCE:
1 = ROSS, 1971
2 = CATER, ET.AL., 1973
3 = YOUNG AND MITCHELL, 1973
4 = YOUNG AND WHITEHEAD, 1975A
5 = YOUNG AND WHITEHEAD, 1975B
6 = MITCHELL, 1976A
7 = MITCHELL, 1976B
8 = MITCHELL, 1976C
9 = SWANSON, 1977
10 = MITCHELL, UNPUBLISHED, 1978

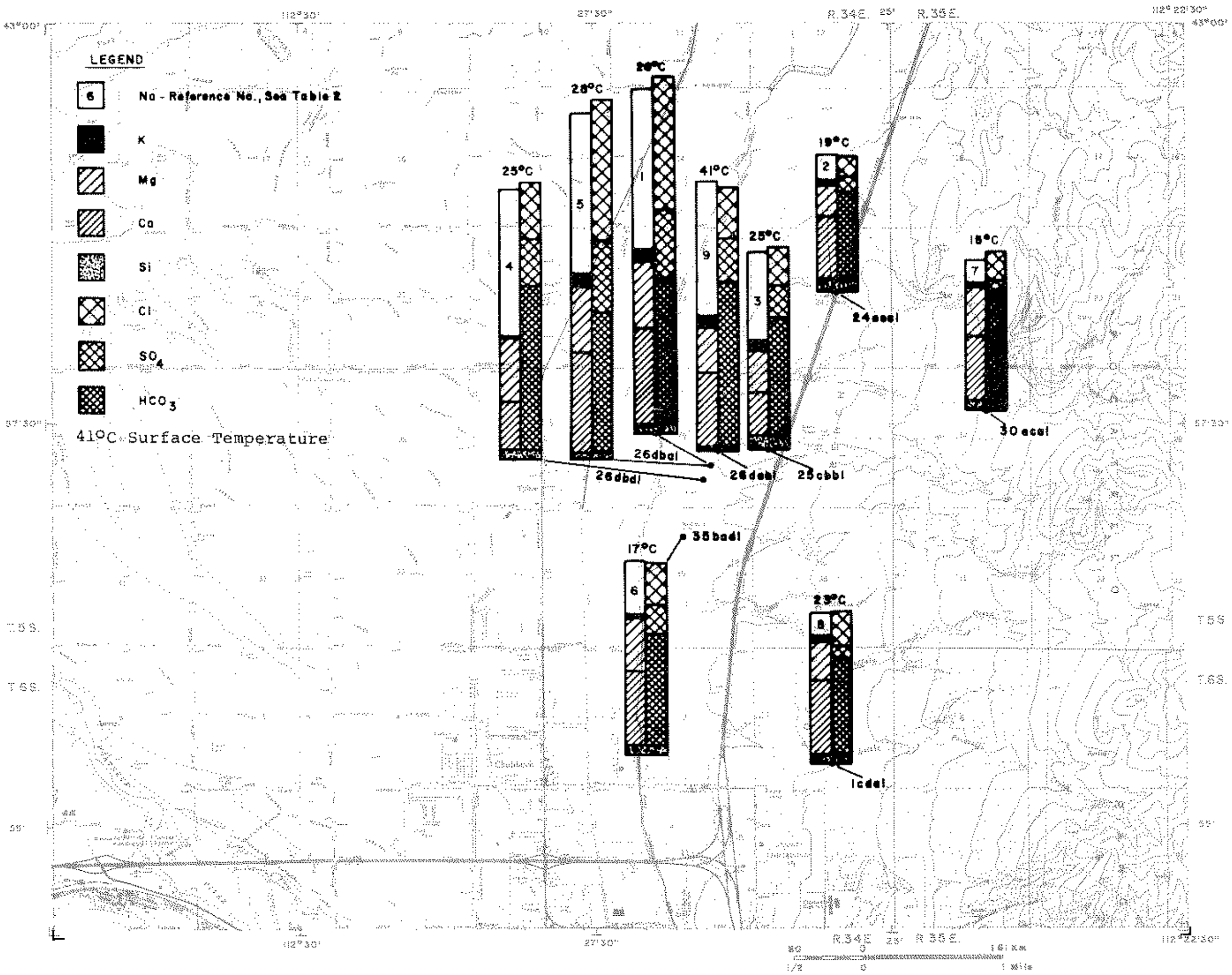
TABLE 3

ESTIMATED AQUIFER TEMPERATURES, ATOMIC AND MOLAR RATIOS OF SELECTED CHEMICAL CONSTITUENTS, FREE ENERGIES OF FORMATION OF SELECTED MINERALS, PARTIAL PRESSURES OF CO_2 GAS AND R VALUES FROM SELECTED THERMAL SPRINGS AND WELLS IN THE TYHEE (NORTH POCATELLO) AREA BANNOCK COUNTY, IDAHO

Spring/Well Identification Number & Name	Discharge (l/min.)	Measured Surface Temperature (°C)	Aquifer Temperatures and Percentage of Cold Water Estimated from Geochemical Thermometers (see footnotes)													Atomic Ratios							Molar Ratios						Free Energies of Formation of			Partial Pressure of CO_2 Gas (atmospheres)	R= Magnesium / (Magnesium + Calcium + Potassium)	Reference Number (See Figs. 13 & 14)
																Sodium/Potassium	Sodium/Calcium	Magnesium/Calcium	Calcium/Fluoride	Chloride/Boron	Chloride/Fluoride	Calcium/Sodium	Calcium/Bicarbonate	Chloride/Carbonate & Bicarbonate	Ammonia/Chloride	Ammonia/Fluoride	Chloride/Sulfate	$\sqrt{Calcium}$/Sodium	Quartz	Chalcedony	Amorphous Silica			
			T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	%9	%11	$\frac{Na}{K}$	$\frac{Na}{Ca}$	$\frac{Mg}{Ca}$	$\frac{Ca}{F}$	$\frac{Cl}{B}$	$\frac{Cl}{F}$	$\frac{Ca}{Na}$	$\frac{Ca}{HCO_3}$	$\frac{Cl}{CO_3 + HCO_3}$	$\frac{NH_4}{Cl}$	$\frac{NH_4}{F}$	$\frac{Cl}{SO_4}$	$\frac{\sqrt{Ca}}{Na}$	ΔG Quartz	ΔG Chalcedony	ΔG Amorphous	PCO_2	$\frac{Mg}{Mg+Ca+K}$ *	
SHOAL SUBDIVISION WELL 5S 34E 26dba1	378.	26	89	91	-24	58	187	187	229	131	118	108	999	86	-	12.0	3.30	0.69	45.26	-	16.33	0.30	0.33	0.91	-	-	3.96	6.29	1.05	0.47	-0.26	0.02061	37.8	1
RICHARD JONES WELL 5S 34E 24acc1	4542.	19	104	104	-11	74	60	60	376	168	999	183	999	-	-	5.3	0.89	0.59	50.70	-	67.90	1.13	0.32	0.24	-	-	2.96	30.96	1.35	0.75	0.04	0.00283	0.0	2
GERALD JOHNSON WELL 5S 34E 25cbb	30.	25	109	109	-7	80	192	192	254	146	261	166	228	95	94	10.1	4.14	0.99	23.94	-	12.64	0.24	0.18	0.33	-	-	2.52	7.65	1.32	0.74	0.01	0.00856	45.1	3
SHOAL SUBDIVISION WELL 5S 34E 26dbd1	0.	25	92	94	-21	62	47	47	41	56	140	121	99	89	85	100.8	6.20	1.36	21.44	-	8.53	0.16	0.15	0.36	-	-	2.71	4.81	1.11	0.52	-0.20	0.02890	0.0	4
BERT HUTH WELL 5S 34E 26dba1	378.	28	87	89	-26	56	189	189	238	136	98	97	999	81	-	11.3	3.16	0.68	47.64	-	16.68	0.32	0.35	0.99	-	-	4.14	6.51	0.96	0.40	-0.32	0.01627	37.3	5
H RUPP & M JENSEN WELL 5S 34E 35bad1	757.	17	98	100	-16	68	66	66	256	137	999	180	999	-	-	10.0	1.44	0.68	52.83	-	47.41	0.69	0.32	0.36	-	-	3.06	16.57	1.32	0.71	0.00	0.00711	0.0	6
RICHARD JONES WELL 5S 35E 30aca1	30.	15	93	95	-20	63	49	49	334	149	999	182	999	-	-	6.4	0.73	0.80	55.83	-	59.26	1.38	0.29	0.27	-	-	7.13	35.58	1.28	0.67	-0.03	0.00530	0.0	7
HARRY HARDT 6S 34E 1cda1	757.	23	99	100	-15	69	54	54	365	150	207	149	193	94	94	5.6	0.70	0.54	152.75	-	165.92	1.43	0.39	0.35	-	-	5.51	34.31	1.23	0.64	-0.08	0.00827	0.0	8
ROBERT BROWN WELL 5S 34E 26dab1	57.	41	63	68	-46	31	185	185	227	136	999	999	999	-	-	12.1	3.74	0.59	14.57	-	10.37	0.27	0.22	0.31	-	-	2.48	6.41	0.39	-0.15	-0.91	0.01166	33.8	9

T_1=SILICA TEMP ASSUMING QUARTZ EQUILIBRIUM AND CONDUCTIVE COOLING (NO STEAM LOSS)
T_2=SILICA TEMP ASSUMING QUARTZ EQUILIBRIUM AND ADIABATIC EXPANSION AT CONSTANT ENTHALPY (MAX STEAM LOSS)
T_3=SILICA TEMP ASSUMING EQUILIBRIUM WITH AMORPHOUS SILICA
T_4=SILICA TEMP ASSUMING EQUILIBRIUM WITH CHALCEDONY AND CONDUCTIVE COOLING (NO STEAM LOSS)
T_5=NA-K-CA TEMP
T_6=NA-K-CA TEMP CORRECTED FOR MG; IF T_6 AND T_5 THERE WAS NO CORRECTION
T_7=NA-K TEMP
T_8=NA-K-CA TEMP CORRECTED FOR PCO_2
T_9=FOURNIER-TRUESDELL MIXING MODEL 1 TEMP (QUARTZ-NO STEAM LOSS)
T_{10}=FOURNIER-TRUESDELL MIXING MODEL 2 TEMP (QUARTZ-STEAM LOSS)
T_{11}=FOURNIER-TRUESDELL MIXING MODEL 1 TEMP (CHALCEDONY-NO STEAM LOSS)
%9=PERCENT COLD WATER IN T_9 CALCULATION
%11=PERCENTAGE OF COLD WATER IN T_{11} CALCULATION
999=AQUIFER TEMPERATURE AND PERCENTAGE OF COLD WATER CALCULATION NOT POSSIBLE
*=R NOT CALCULATED IF T_5= <70°

FIGURE 13. Composition of groundwater and locations of sampled wells in the Tyhee area. Bar graph shows millimeters per liter per dissolved silica and milliequivalence per liter of anions and cations.



might not be due entirely to thermal conditions. In areas of irrigated agriculture, increases in sodium and chloride concentrations have been known to be related to mixing of groundwater and irrigation water. The limited number of data points makes interpretations highly speculative.

A trilinear diagram is another useful way to display water chemistry data. Figure 14 is a trilinear plot of the Tyhee water quality data. The diagram displays the two water types, a dominantly sodium bicarbonate water represented by the warmer wells (numbers 1, 3, 4, 5 and 9; see table 2 for their location) and a calcium sodium bicarbonate type in the cooler wells (2, 6, 7 and 8). Some mixing of thermal and cold water may occur, perhaps between water represented by samples 9 and 7 to yield sample 2 water or between samples 1 and 7 to yield sample 6 water. However, the scatter on the trilinear diagram indicates that simple mixing models will not adequately describe the water chemistry of the Tyhee area. Partial reequilibration appears to have occurred in samples 1 and 5 water which are from the same well. Their chloride (Cl) content is much greater, and that of bicarbonate (HCO_3) is much less than samples 1, 9 and 6; in percentage reacting values the excess Cl is nearly equal to the deficiency of HCO_3, as though samples 1 and 5 water had undergone ion for ion exchange between HCO_3 and Cl.

AQUIFER TEMPERATURES

Preliminary evaluations of geothermal systems are being successfully conducted using chemical geothermometers. In the Raft River Valley of southeastern Idaho, the reliability of these thermometers has been tested by deep drilling. The silica and Na-K-Ca predicted aquifer temperatures (Young and Mitchell, 1973) and mixing model calculations (Young and Mitchell, 1973, unpublished data) agreed very closely (within 10°C) with temperatures found at depth (Kunze, 1975). This provides some measure of confidence in applying the same methods to similar areas of the state.

The degree of reliance to be placed on a chemical geothermometer depends on many factors. A detailed description of the basic assumptions, cautions, and limitations for these chemical geothermometers is included in the Selected References. The basic assumption is that the chemical character of the water obtained by temperature dependent equilibrium reactions in the thermal aquifer is conserved from the time the water leaves the aquifer until it reaches the surface. The concentration of certain chemical constituents dissolved in the thermal water can, therefore, be used to estimate aquifer temperatures.

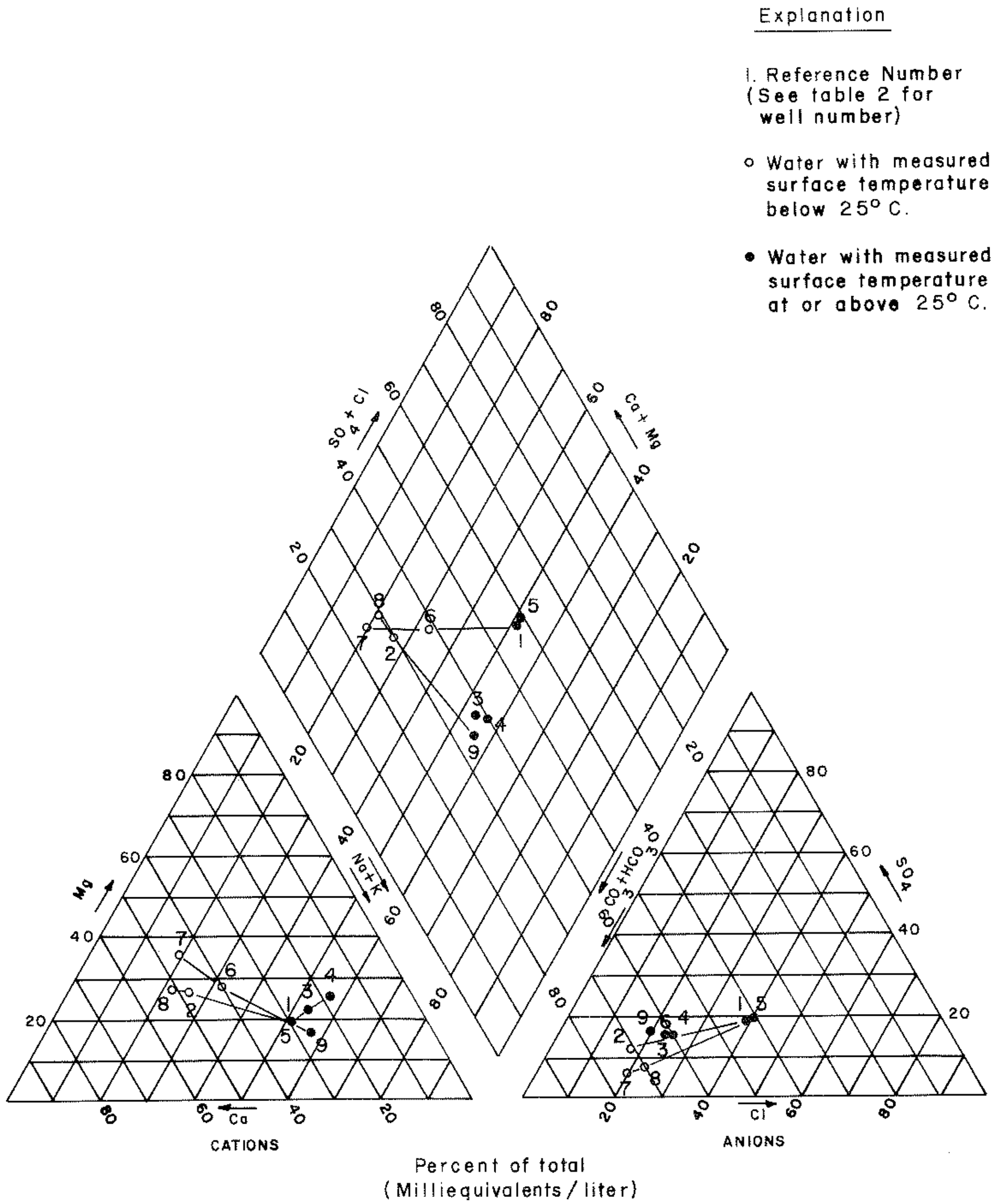


FIGURE 14. Trilinear diagram showing variations of chemical constituents in water sampled from the Tyhee area.

Aquifer temperatures calculated from the silica and Na-K-Ca chemical geothermometers, and from mixing models, as well as the atomic ratios of selected elements found dissolved in the thermal waters of the Tyhee area are given in table 3. These were calculated from the concentrations in table 2. The higher temperature waters are distinctive in exhibiting higher magnesium/calcium (Mg/Ca), sodium/calcium (Na/Ca) and lower calcium/fluoride (Ca/F) and chloride/flouride (Cl/F) ratios than found in lower temperature waters of the Tyhee area. The similarity in each of these individual ratios for the higher temperature waters is evidence that these waters are genetically related. Water discharged from wells having lower measured surface temperatures also have similar Mg/Ca, Na/Ca, Ca/F, and Cl/F ratios indicating that the lower temperature waters are genetically related.

As shown in table 3, for any one well, there is little agreement obtained among the various chemical geothermometers. An exception is well 5S-34E-35badl where chalcedony (T_4) and sodium-potassium-calcium (Na-K-Ca) predicted 68° and 66°C, respectively. Looking at data from all wells, however, most agreement seems to be with the chalcedony predicted temperatures where temperatures between 60 and 70°C seem most common for lower temperature water. Higher temperature waters show that for most wells sampled, the chalcedony chemical geothermometer predicts temperature near 60-70°C (table 3, column T_4). An exception is the hot well, where the quartz chemical geothermometer predicts a maximum subsurface temperature of 63°C, in agreement with chalcedony for lower temperature wells. A milky quartz was encountered in the drill hole for this well when the driller penetrated the thermal aquifer as shown by drill cuttings obtained from the owner. A mixing model for this well (table 3, column T_8) predicts a maximum subsurface temperature of 80°C.

In summary, data from tables 2 and 3 and figures 13 and 14, therefore, indicate two distinct chemical water types in the area. The warmer thermal waters are represented most closely by the chemical composition of well 5S-34E-26dabl. Surface temperatures in other wells of this water type may be caused by conductive cooling of this water as it ascends up fault planes and spreads laterally into the aquifer system(s) or by mixing of thermal and nonthermal waters. The thermal water may not have reached a temperature higher than 80°C before cooling began or reequilibrated chemically in a shallow aquifer at 80°C. Cooler thermal waters may be mixed thermal and cold groundwaters, or may be cold groundwaters heated slightly by processes not readily apparent.

CONCLUSIONS AND RECOMMENDATIONS

Thermal waters of at least two types exist in the Tyhee area based on chemical analyses and synthesis of the analyzed data. Highest probable aquifer or subsurface temperatures which might be encountered by drilling for these waters would seem to be 80°C represented by the quartz mixing model 1 (table 3, column T_8) for well 5S-34E-26dabl. Lowest probable temperature for this thermal water would be represented by the surface discharge temperature of the same well, i.e., 41°C. The most likely temperature to be anticipated by deeper drilling may be represented by the quartz chemical geothermometer for this well at 63°C.

Further geochemical studies should collect more chemical information for wells from which samples were not obtained for this study. A further attempt at hydrogen-deuterium and oxygen 18-oxygen 16 isotope sample collection should be made through well head access ports installed to minimize mixing of water with atmospheric gasses. These data could shed more light on mixing probability of thermal and nonthermal water, further define the limits of thermal water occurrence in the Tyhee area, and may indicate possible recharge areas for both types of water. This information is unobtainable from existing data and would be necessary for adequate assessment and regulation of the resource should large scale withdrawal of geothermal waters in the area be attempted.

OTHER METHODS OF INVESTIGATION

GEOTHERMAL GRADIENT AND HEAT FLOW

Although not extremely reliable as predictors of drilling depths, geothermal gradient measurements have been used in geothermal investigations to establish boundary conditions or possible limits to which one might reasonably expect water to be circulating. Therefore, temperature gradient measurements were made in seven unused wells in the Tyhee and adjacent areas. These wells ranged in depth from 30 to 230 m. Locations of four of the seven holes are shown on figure 15. The measured gradients are shown in figures 16 through 22. As seen from the figures, the temperature gradients are not consistent and are too variable to determine an extremely reliable overall temperature gradients for the Tyhee area. The temperature gradients range from nearly isothermal (figure 22) to a maximum of 190°C/km. Most gradients were above normal (33°C/km). Four of the six wells from which gradients were obtained exhibited a lower gradient in the upper section of the well and a gradient of greater magnitude in the deeper parts of the well bore (figures 16, 17, 18 through 20). This could be due to one or more of several effects including thermal conductivity changes of the underlying sediments and rock, vertical or lateral groundwater movement, topographic effects, seasonal fluctuations and/or irrigation practices. The most reasonable gradient appears to be about 60°C/km given in the bottom portions of two wells shown in figures 16 and 18 (5S-35E-30aab1 and 5S-34E-36dac1).

The greater reliability of heat-flow measurements over simple temperature-gradient measurements or calculations in assessing an area's geothermal potential is well known. The geothermal gradient may be viewed as the potential difference between the earth's deeper layers and that found at the surface, and is dependent on the ability of the intervening rock layers to conduct heat (thermal conductivity). Heat flow measurements take this thermal conductivity into account, and, therefore, are uniform with depth, while abrupt and sometimes large variations in geothermal gradient occur with depth due to changes in thermal conductivity. A high heat flow, therefore, may indicate the presence of an intense heat source (regional or local) in the subsurface, while a high geothermal gradient may only reflect a lower thermal conductivity.

Although the thermal conductivity of the intervening rock layers in the Tyhee area is not exactly known, reason-

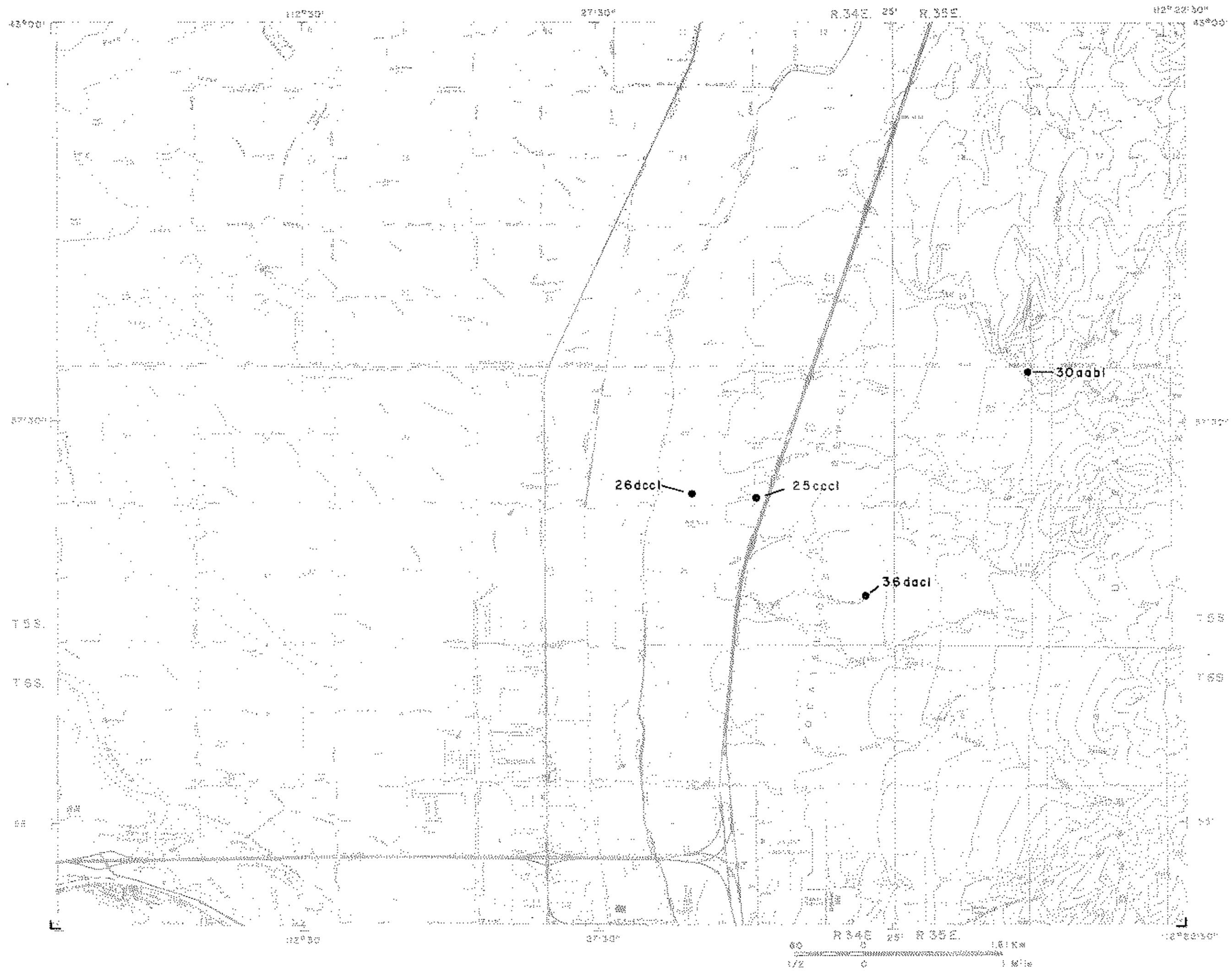


FIGURE 15. Location of temperature-gradient holes in the Tyhee area. Measured boreholes outside the Tyhee area are not shown.

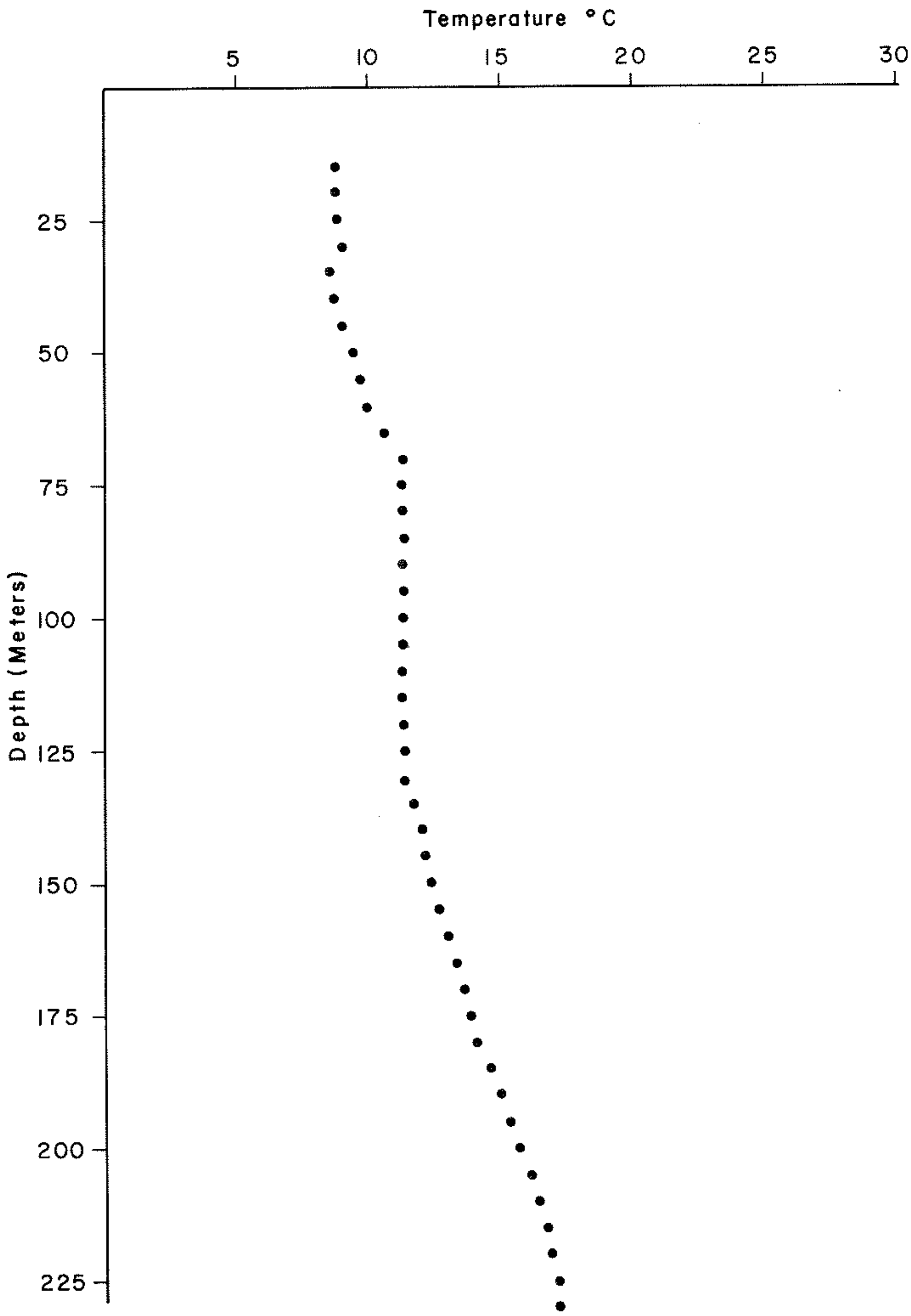


FIGURE 16. Temperature depth diagram for well 5S-35E-30aabl.

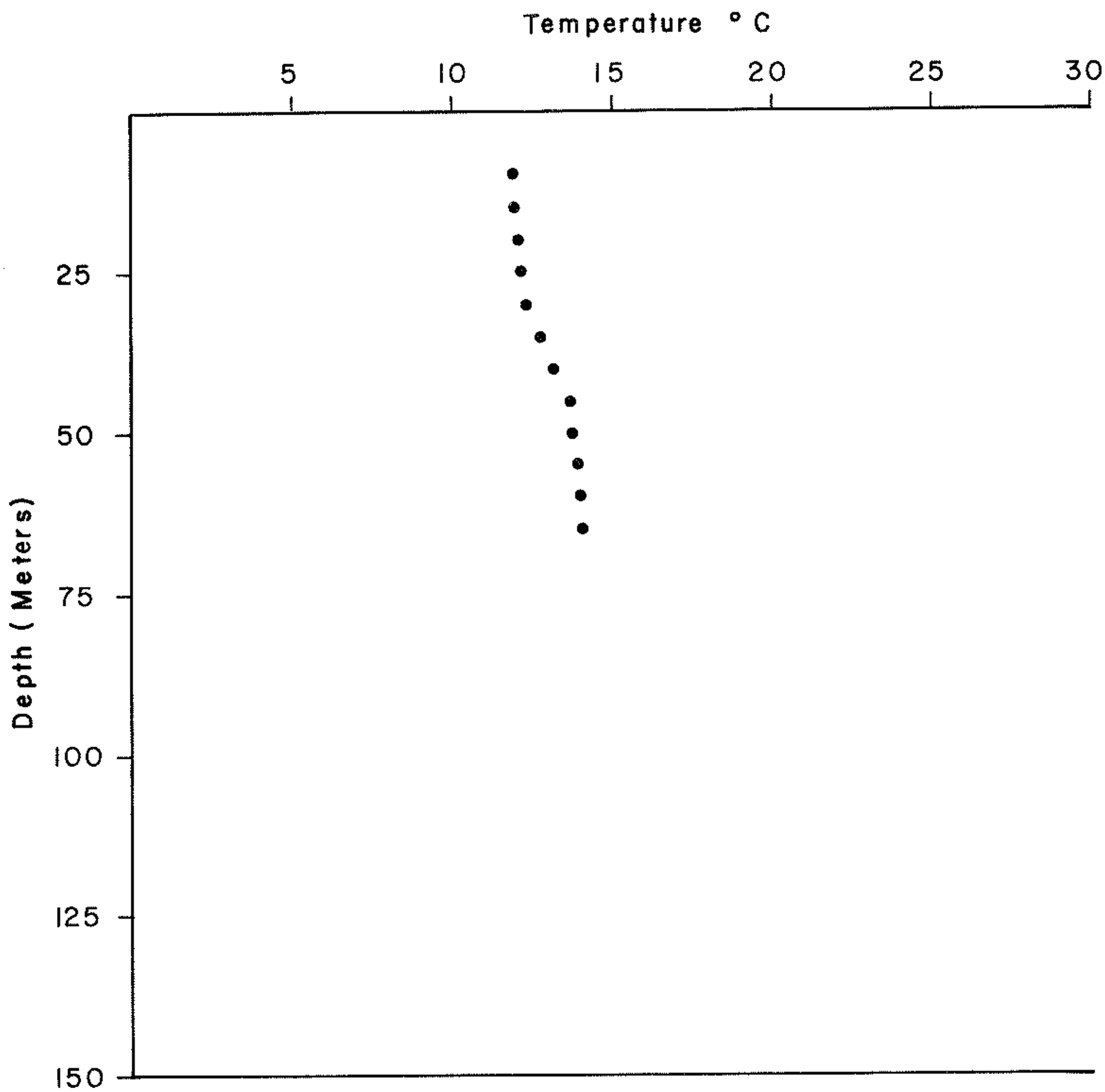


FIGURE 17. Temperature depth diagram for well 6S-34E-2cdcl.

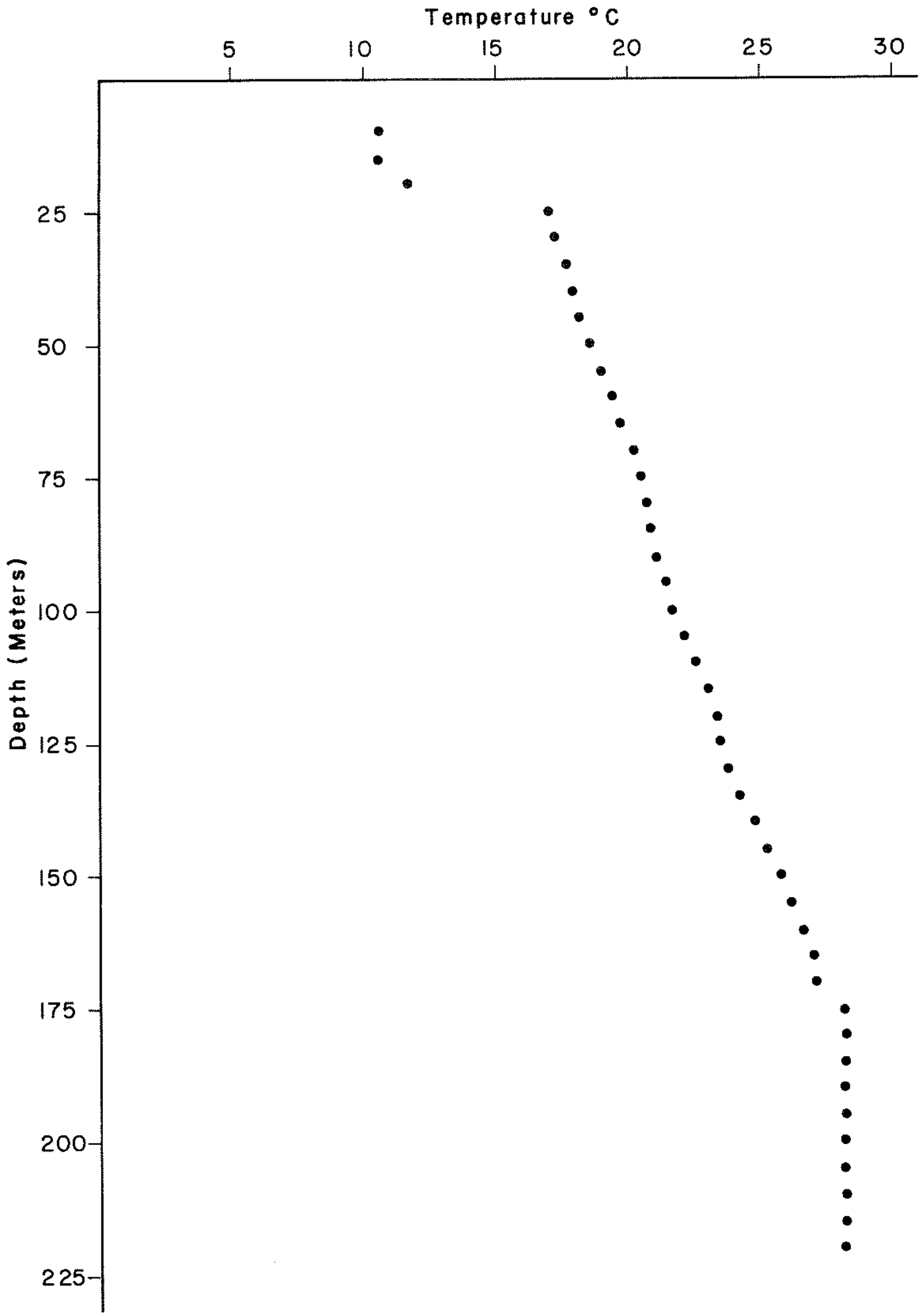


FIGURE 18. Temperature depth diagram for well 5S-34E-36dac1.

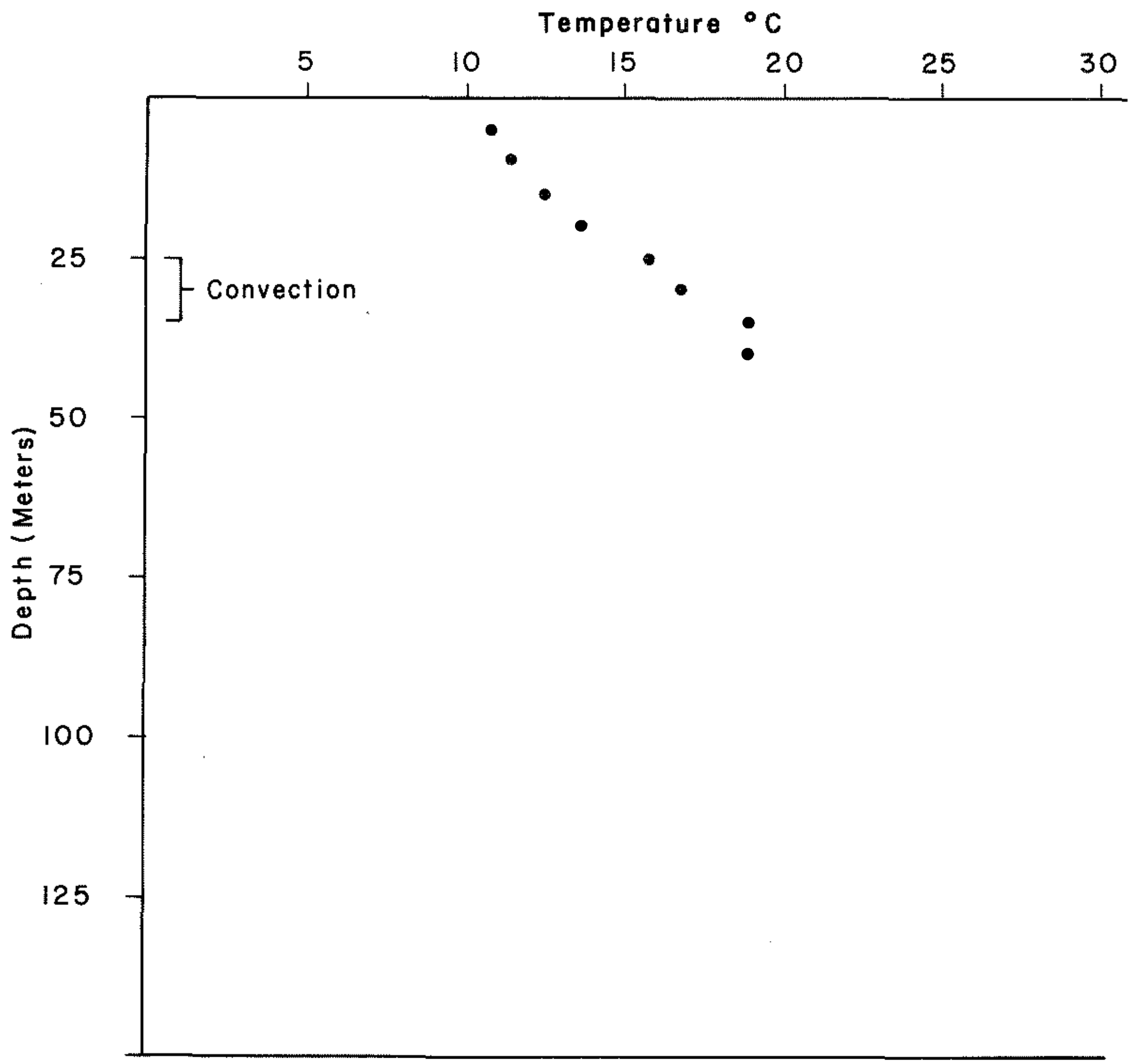


FIGURE 19. Temperature depth diagram for well 5S-34E-26dccl.

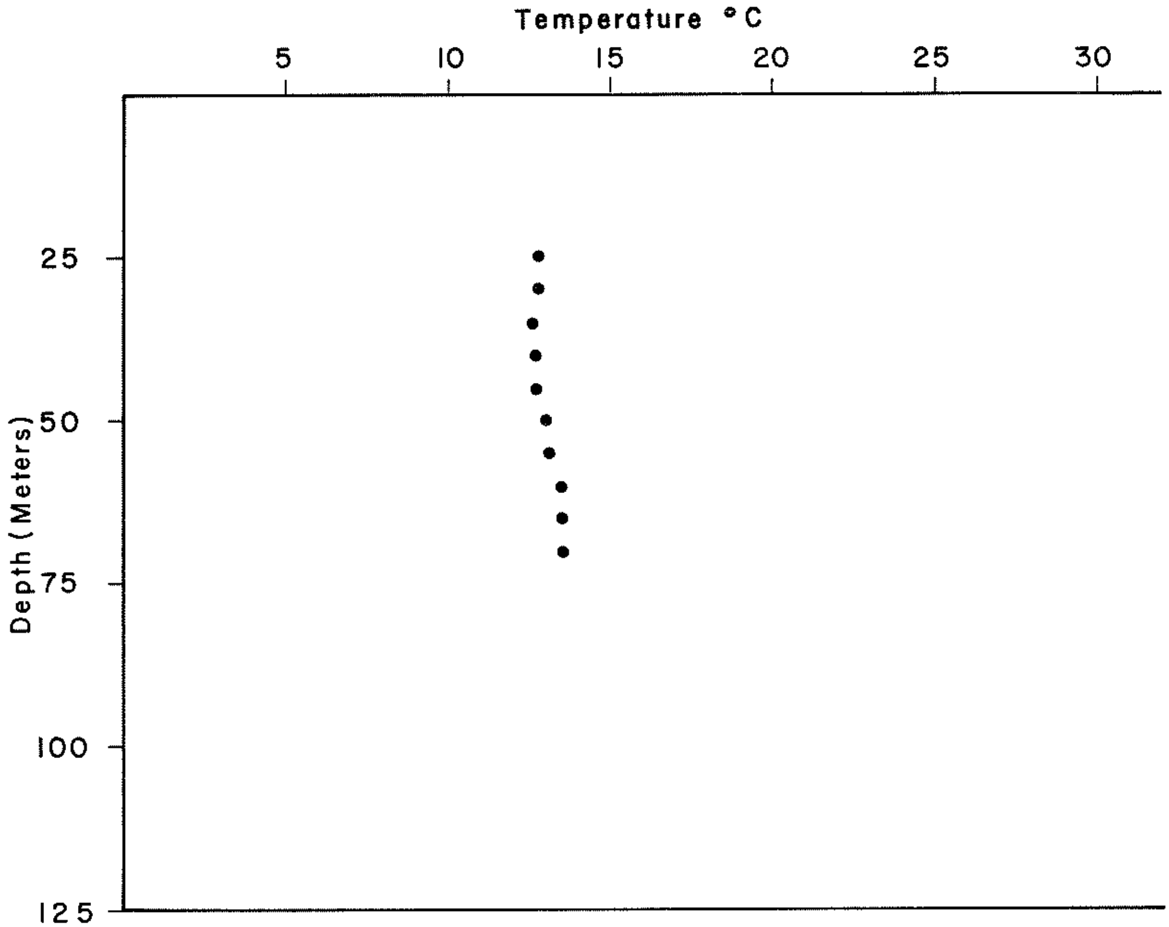


FIGURE 20. Temperature depth diagram for well 6S-35E-18cad1.

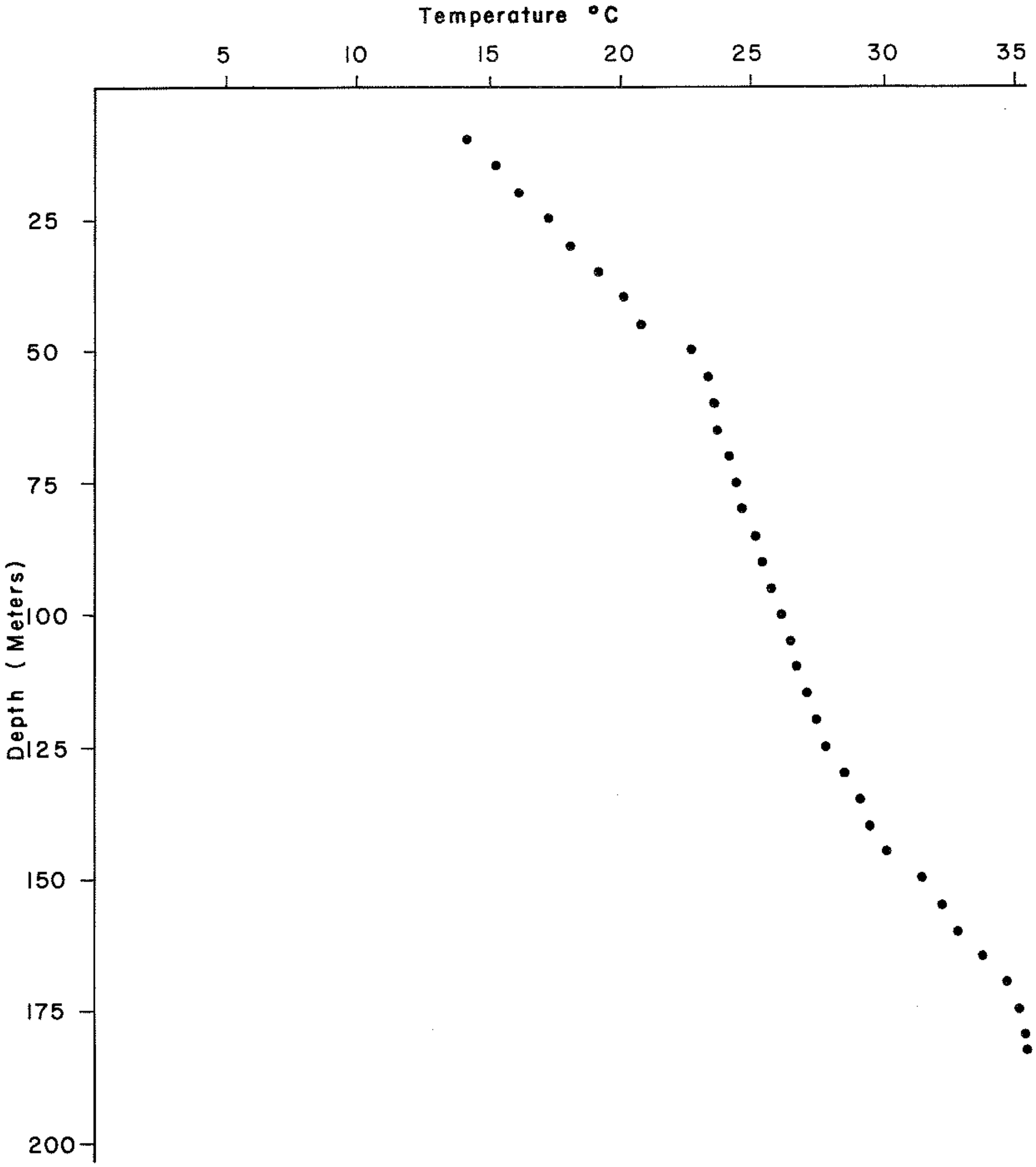


FIGURE 21. Temperature depth diagram for well 5S-34E-25cccl.

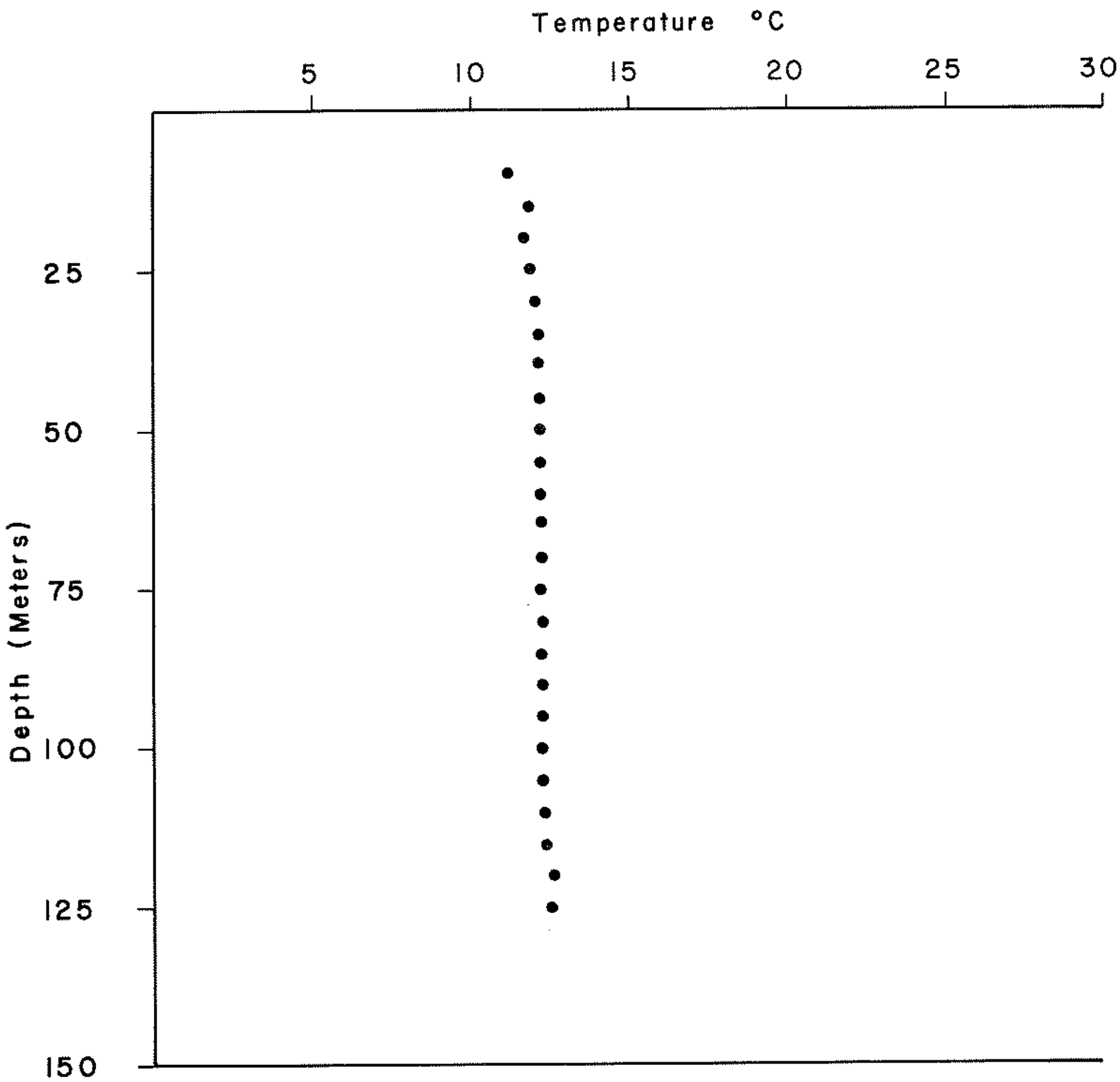


FIGURE 22. Temperature depth diagram for well 6S-35E-18cbbl.

able heat flow assumptions can be made by simply knowing the limits of thermal conductivity of the types of rocks found in the area. For example, unconsolidated, poorly sorted sands and gravels usually exhibit a thermal conductivity in thermal conductivity units (TCU) between 2.0 and 5.0 microcalories per square centimeters per second $\mu cal/cm^2 sec$ giving a heat flow, in heat flow units (HFU), of from $60^{\circ}C/km \times 2.0$ TCU = 1.2 $\mu cal/cm^2 sec$ (1.8 HFU) as a lower limit and $60^{\circ}C/km \times 5$ TCU - 3 HFU as an upper limit. A heat flow of 3 HFU would be twice that which is considered normal (1.5 HFU) for most of the United States, but which appears to be typical of the margins of the Snake River Plain region (Brott and others, 1976). A heat flow of this magnitude would mean the hottest thermal water (41°C) would have to circulate to a depth of about 1000 m or 1 km in this area. The cause of this heat flow is presently not known. Speculations are a crustal heat source, a mantle heat source due to crustal thinning or convective heat transfer along fracture zones due to upwelling and lateral spread of thermal water.

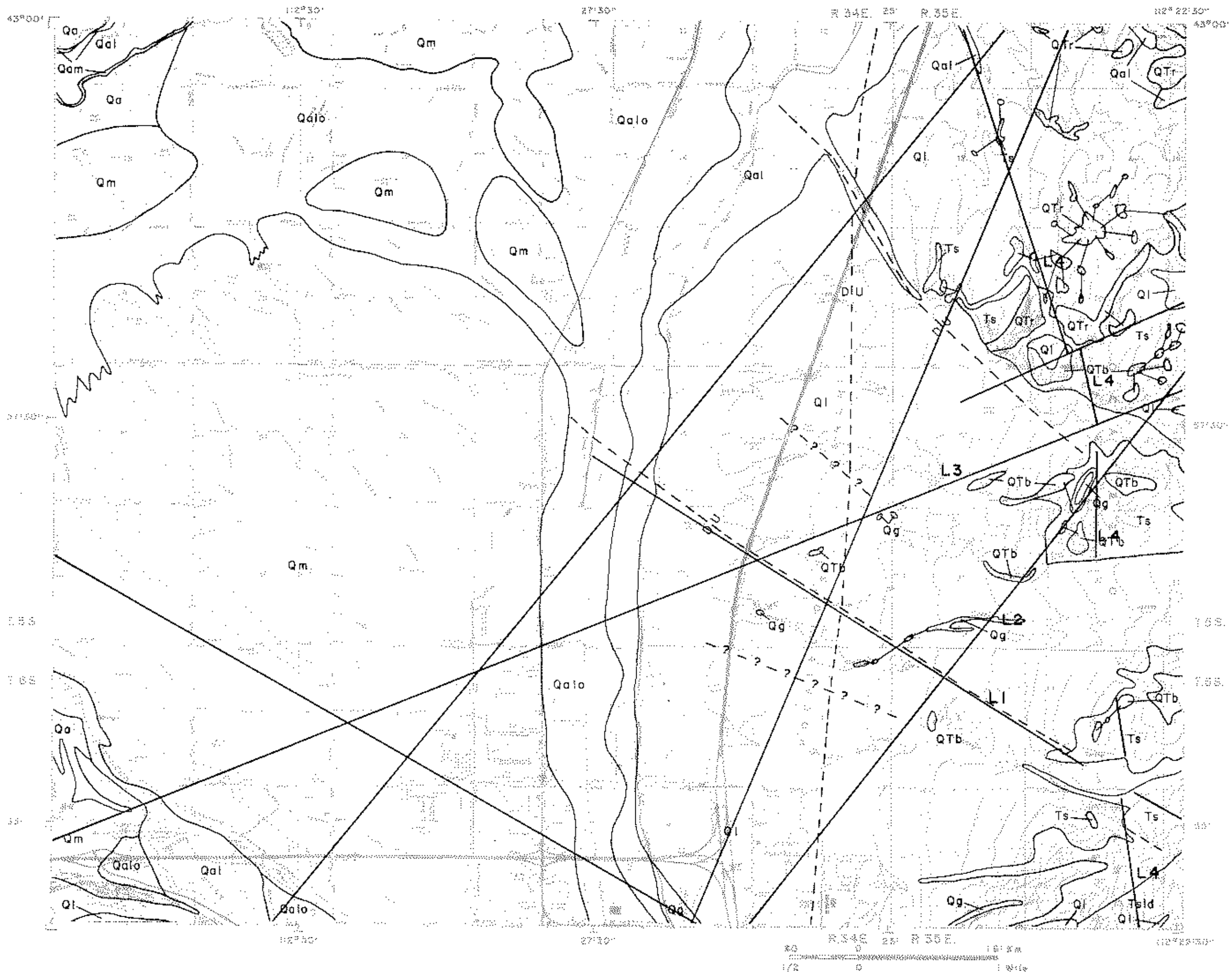
LANDSAT IMAGERY

Landsat imagery, enhanced by the USGS Earth Resources Observation Systems (EROS) data center, at scale of 1:1,000,000, 1:500,000, 1:250,000, was used to augment structural interpretations obtained by gravity, magnetic, and well log data within the study area. Linear features observed on these false color infrared images are shown on figure 23.

Interpretation of structure from the gravity, magnetics, and lithology from well logs agree somewhat with linear data from the Landsat digital imagery. However, the pronouncement of a linear or one trend of linears verus another on the imagery can be the result of many factors, including cultural trends, rock-type, vegetation, depositional features, time of day or year the image was obtained and process parameters selected in obtaining a hard copy of the image.

Although the north-south fault (inferred from gravity data) is thought to be younger than the north-west trending fault, (also inferred by gravity data), no evidence of the existence of the north-south inferred fault could be seen on Landsat imagery while a northwest trending linear (L_1, figure 23) does show on the Landsat images exactly where the northwest fault is inferred at the surface. This northwest linear extends somewhat discontinuously across the Pocatello Range into the lower reaches of Rapid (Rabbit) Creek north of Inkom and to the Portneuf Range where it becomes indistinguishable near the base of the Portneuf Range. This

FIGURE 23. Map showing linear features in the Tyhee area and their relation to geology. (Geology modified from Trimble, 1976)



linear approximately corresponds to an arcuate trend of regularly spaced thermal springs first noted by Mitchell and others (1980, p. 21-22) which connects the Tyhee area with Portneuf River Warm Springs and Steamboat Springs in Caribou County. A southwest trending linear (L_3, figure 23) extends across the study area and is found to coincide with a fault mapped by Trimble (1976) in the Pocatello Range to the east of the study area.

The other linears shown on figure 5 coincide with no known gravity, magnetic or lithologic pronounced features derived from well log data. Some linears (L_2, L_3 and L_4) do, however, seem to be associated with small outcroppings of Trimble's (1976) High Level (Lower Pleistocene and Upper Pliocene) Basalt.

SYNOPSIS

CONCLUSIONS

The marginal position of the Tyhee area to two structural provinces (Snake River Plain and Basin and Range) suggested to the authors that geology in the area might be somewhat complex. This has been shown to be correct. Gravity and magnetic data indicate that the Snake River Plain margin may consist of fault dislocations as wide as 2.5 km and is probably located further west than originally believed. Gravity data indicate concealed north-south normal faulting separating bedrock of the Bannock Range to the east from similar materials overlain by unconsolidated sediments on the down-dropped side. This is interpreted to be a major structure of the Snake Plain boundary fault zone. Similar faulting, but apparently older and of lesser magnitude intersects the north-south structure near the center of the area. Shallow wells drilled in the pediment also indicate a northwest-southeast fault in the position of the gravity inferred fault. Landsat imagery also indicates the presence of the southwest-northeast fault by a linear feature trending through the area.

Hot water discovered by well drilling and a former thermal spring appear to be both spatially and genetically related to the intersection of the above mentioned faults. The quartz chemical geothermometer and a mixing model indicate that thermal water equilibrated last in an aquifer or fault structure at a temperature of between 63 and 80°C. Geothermal gradient measurements indicate a gradient of 60°C/km and speculative thermal conductivity values indicate heat flow of from 1.2 to 3.0 HFU with a probable value of about 3 HFU for the area. This would indicate drilling depths of about 1000 m for 63°C temperature.

RECOMMENDATIONS

As fault intersections appear to be the most favorable target to produce the hottest water in this area, it would be highly desirable to determine the exact location and attitudes of faults in the area before a deep drilling program is begun.

Seismic survey - reflection and refraction - are not likely to give good results in the very shallow subsurface where data is most needed but might indicate deeper structures and shed more light on the nature of the basin and range - Snake River Plain boundary.

Electrical prospecting methods such as spontaneous polarization resistive or telluric current fields might give good results in the shallow subsurface in the area. Magnetotelluric or audiomagnetic telluric prospecting would have an added advantage of deep penetration as well, and are probably the least costly of the geophysical surveys which could be run.

Monitoring holes should be drilled and aquifer tests conducted to determine aquifer characteristics, and possibilities of well interference should more thermal wells be drilled in the area. The monitoring holes would also be valuable to more adequately determine structural and stratigraphic controls on thermal and nonthermal water in the area.

Hydrogen-deuterium and oxygen 18-oxygen 16 isotope ratios from both thermal and nonthermal water in the area and adjacent areas should be run to indicate origin of the thermal waters. These tests would be important should large scale withdrawal of thermal water be attempted.

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APPENDIX

TABLE 1

DATA REDUCTION AND GRAVITY CORRECTIONS
GRAVITY SURVEY - TYHEE AREA
BANNOCK COUNTY

Station Number	Time Read	Dial Divisions: Average Reading	Dial Divisions: Corrected for Drift	Milligals	Elevation (feet)	Bouguer Correction (= 2.0)	Latitude Correction (43 00)	Corrected through Latitude	Terrain Correction	G
October 28, 1978										
BS 1	10:40	1931.7	1900.00	180.46	4460	198.28	4.56	202.84	.06	202.90
1	10:55	1927.3	1895.5	180.03	4491	199.98	4.56	204.54	.12	204.66
2	11:10	1936.6	1904.6	180.90	4458	198.58	4.56	203.14	.04	203.18
3	11:20	1930.6	1898.5	180.32	4479	199.44	4.56	204.00	.02	204.02
4	11:55	1946.3	1913.9	181.78	4471	200.35	4.56	204.91	.01	204.92
5	11:35	1962.3	1930.1	183.32	4470	201.83	4.56	206.39	0	206.39
BS 1	12:05	1932.5	--	--	--	--	--	--	--	--
6	12:30	1965.2	1932.4	183.53	4473	202.24	4.56	206.80	0	206.80
7	12:45	1970.7	1937.6	184.04	4470	202.55	4.56	207.11	0	207.11
8	1:05	2008.1	1974.7	187.56	4460	205.38	3.26	208.64	0	208.64
BS 1	1:25	1933.7	--	--	--	--	--	--	--	--
9	1:50	1998.5	1964.5	186.59	4465	204.75	3.26	208.01	0	208.01
10	2:00	1984.4	1950.3	185.24	4473	203.95	3.26	207.21	0	207.21
11	2:20	1979.3	1944.9	184.73	4462	202.69	3.26	205.95	.01	205.96
12	2:35	1958.7	1924.2	182.76	4474	201.54	3.26	204.80	.01	204.81
BS 1	2:50	1934.6	--	--	--	--	--	--	--	--
13	3:05	1985.1	1950.6	185.27	4463	203.30	3.26	206.56	.03	206.59
14	3:20	2038.2	2003.9	190.33	4459	208.08	3.26	211.34	.06	211.40
15	3:35	2025.3	1991.2	189.12	4490	209.00	3.26	212.26	.12	212.38
BS 1	3:55	1933.7	--	--	--	--	--	--	--	--
October 29, 1978										
BS 1	9:25	1929.7	1900.0	180.46	4460	198.28	4.56	202.84	.06	202.90
*8	9:40	2005.3	1974.8	187.57	4460	205.39	3.26	208.65	0	208.65

Table 1. Data Reduction and Gravity Corrections (continued)

Station Number	Time Read	Dial Divisions Average Reading	Dial Divisions Corrected for Drift	Milligals	Elevation (feet)	Bouguer Correction (= 2.0)	Latitude Correction (43 00)	Corrected through Latitude	Terrain Correction	G
October 29, 1978 (cont'd.)										
16	10:15	1931.2	1898.8	180.35	4440	196.80	7.17	203.97	.06	204.03
17	10:25	1913.7	1880.9	178.65	4458	196.33	7.17	203.50	.05	203.55
BS 1	10:40	1933.3	--	--	--	--	--	--	--	--
18	11:00	1912.6	1879.4	178.51	4459	196.26	7.17	203.43	.04	203.47
19	11:15	1889.4	1856.3	176.31	4470	194.82	7.17	201.99	.04	202.03
20	11:30	1873.4	1840.5	174.81	4460	192.63	7.17	199.80	.05	199.85
21	11:45	1856.6	1823.8	173.22	4462	191.18	7.17	198.35	.08	198.43
BS 1	12:00	1932.6	--	--	--	--	--	--	--	--
November 2, 1978										
BS 1	10:05	1928.4	1900.0	180.46	4460	198.28	4.56	202.84	.06	202.90
22	10:25	1848.3	1880.8	172.75	4469	191.19	7.17	198.36	.11	198.47
23	11:05	1769.9	1738.4	165.11	4567	190.26	7.17	197.43	.23	197.66
24	11:20	1722.3	1689.9	160.51	4649	191.28	7.17	198.45	.16	198.61
25	11:30	1706.5	1673.9	158.99	4724	194.90	7.17	202.07	.26	202.33
BS 1	11:50	1932.8	--	--	--	--	--	--	--	--
BS 1	12:55	1932.1	--	--	--	--	--	--	--	--
28	1:20	1555.4	1523.5	144.70	5103	206.59	7.17	213.76	.53	214.29
27	1:35	1657.6	1625.7	154.41	4952	205.95	7.17	213.12	.46	213.58
26	1:50	1701.1	1688.1	160.34	4829	203.45	7.17	210.62	.37	210.99
BS 1	2:05	1932.2	--	--	--	--	--	--	--	--
29	3:05	1948.8	1916.3	182.01	4480	201.20	3.91	205.11	.03	205.14
BS 1	3:15	1932.5	--	--	--	--	--	--	--	--
30	3:30	1864.4	1832.0	174.00	4482	193.33	5.87	199.20	.09	199.29
31	3:45	1891.3	1858.9	176.56	4460	194.38	5.87	200.25	.05	200.30
32	3:50	1904.6	1872.3	177.83	4481	197.09	5.87	202.96	.02	202.98

33	4:05	1928.0	1895.8	180.06	4475	198.91	5.87	204.78	.02	204.80
34	4:15	1937.3	1905.2	180.96	4472	199.60	5.87	205.47	.02	205.49
35	4:25	1956.5	1924.6	182.80	4454	200.21	5.87	206.08	.02	206.10
36	4:40	1945.0	1913.2	181.72	4468	200.09	5.87	205.96	.02	205.98
BS 1	4:55	1931.7	--	--	--	--	--	--	--	--
37	5:20	1704.0	1672.2	158.83	4874	205.03	3.91	208.94	.40	209.34
38	5:35	1758.0	1725.9	163.93	4780	203.68	3.91	207.59	.34	207.93
39	5:40	1848.1	1815.9	172.47	4679	205.30	3.91	209.21	.27	209.48
40	5:50	1903.6	1871.1	177.72	4622	206.64	3.91	210.55	.19	210.74
41	5:55	1945.9	1913.3	181.73	4568	206.95	3.91	210.86	.14	211.00
BS 1	6:00	1932.9	--	--	--	--	--	--		

November 5, 1978

BS 1	9:50	1928.3	1900.0	180.46	4460	198.28	4.56	202.84	.06	202.90
42	10:40	1670.6	1640.8	(Station moved and reading not used)				--	--	--
BS 1	11:30	1931.3	--	--	--	--	--	--	--	--
43	12:10	1581.5	1548.6	147.09	5080	207.41	3.91	211.32	.45	211.77
44	12:35	1522.3	1488.4	141.37	5157	206.96	4.56	211.52	.47	211.99
45	12:55	1519.8	1485.0	141.05	5178	208.08	5.22	213.30	.49	213.79
46	1:25	1593.8	1557.8	147.96	5065	207.25	5.87	213.12	.51	213.63
47	1:45	1568.1	1531.2	145.43	5094	206.70	6.52	213.22	.52	213.74
48	2:25	1677.2	1638.6	155.63	4947	206.83	6.52	213.35	.45	213.80
BS 1	2:55	1939.3	--	--	--	--	--	--	--	--
BS 1	3:35	1937.8	--	--	--	--	--	--	--	--

November 7, 1978

BS 1	8:50	1948.4	1900.0	180.46	4460	198.28	4.56	202.84	.06	202.90
*5	9:15	1977.9	1928.8	183.20	4470	201.71	4.56	206.27	0	206.27
49	9:40	2015.4	1965.3	186.66	4471	205.23	3.91	209.14	.06	209.20
BS 1	9:55	1950.7	--	--	--	--	--	--	--	--
50	10:10	1908.8	1857.4	176.42	4478	195.47	5.22	200.69	.08	200.77
BS 1	10:20	1951.7	--	--	--	--	--	--	--	--
51	10:30	1939.8	1888.1	179.33	4458	197.01	5.22	202.23	.03	202.26
52	10:40	1941.2	1889.4	179.46	4474	198.24	5.22	203.46	.02	203.48
53	11:01	1954.0	1902.1	180.66	4476	199.58	5.22	204.80	.01	204.81

Table 1. Data Reduction and Gravity Corrections (continued)

Station Number	Time Read	Dial Divisions Average Reading	Dial Divisions Corrected for Drift	Milligals	Elevation (feet)	Bouguer Correction (= 2.0)	Latitude Correction (43 00)	Corrected through Latitude	Terrain Correction	G
				November 7, 1978 (cont'd.)						
54	11:15	1960.4	1908.5	181.27	4472	199.91	5.22	205.13	.01	205.14
55	11:30	1970.7	1918.7	182.24	4467	200.54	5.22	205.76	.01	205.77
56	11:55	1989.8	1937.7	184.04	4446	200.90	5.22	206.12	.01	206.13
BS 1	12:05	1952.3	--	--	--	--	--	--	--	--
57	1:05	2012.5	1960.1	186.17	4468	204.54	3.91	208.45	0	208.45
58	1:15	2008.2	1955.8	185.76	4464	203.85	3.91	207.76	0	207.76
59	1:25	1992.6	1040.1	184.27	4468	202.64	3.91	206.55	0	206.55
BS 1	1:35	1952.5	--	--	--	--	--	--	--	--
61	1:50	1959.9	1907.5	181.17	4477	200.16	3.91	204.07	.01	204.08
60	2:05	1980.5	1928.3	183.15	4462	201.11	3.91	205.02	.01	205.03
62	2:30	1941.8	1890.0	179.51	4474	198.29	6.52	204.81	.04	204.85
63	2:40	1948.1	1896.5	180.13	4470	198.64	6.52	205.16	.03	205.19
64	3:00	1948.7	1897.4	180.22	4474	199.00	6.52	205.52	.03	205.55
65	3:10	1935.9	1884.8	179.02	4476	197.94	6.52	204.46	.03	204.49
66	3:20	1910.1	1859.1	176.58	4478	195.63	6.52	202.15	.04	202.19
BS 1	3:30	--	--	--	--	--	--	--	--	--
67	3:50	1887.0	1836.0	174.38	4453	191.72	6.52	198.24	.08	198.32
68	4:05	1967.3	1816.1	172.49	4474	191.27	6.52	197.79	.09	197.88
71	4:45	1842.3	1790.5	170.06	4575	195.76	5.22	200.98	.14	201.12
70	4:55	1821.7	1769.8	168.10	4559	192.71	5.87	198.58	.13	198.71
69	5:15	1800.6	1748.4	166.06	4566	191.18	+6.52	197.70	.14	197.84
BS 1	5:30	1952.5	--	--	--	--	--	--	--	--
				November 11, 1978						
BS 1	9:45	1936.5	1900.0	180.46	4460	198.28	4.56	202.84	.06	202.90
72	10:00	1989.9	1953.3	185.52	4449	202.59	2.61	205.20	.01	205.21
73	10:15	1991.6	1954.9	185.68	4466	203.91	2.61	206.52	.01	206.53

74	10:25	2007.4	1970.6	187.17	4459	204.92	2.61	207.54	0	207.54
75	10:35	2019.6	1982.7	188.32	4460	206.14	2.61	208.75	0	208.75
76	11:00	2029.0	1991.8	189.18	4442	205.77	1.96	207.73	0	207.73
BS 1	11:15	1937.5	--	--	--	--	--	--	--	--
77	11:40	2015.6	1977.5	187.82	4454	205.23	1.96	207.19	0	207.19
78	11:50	2033.4	1995.0	189.49	4436	205.67	1.96	207.63	0	207.63
79	12:10	2024.7	1985.5	188.58	4438	204.89	1.96	206.85	.01	206.86
80	12:25	2025.9	1986.0	188.63	4445	205.42	1.96	207.38	.01	207.39
81	12:30	2051.8	2011.6	191.06	4454	208.47	1.96	210.43	.02	210.45
BS 1	12:45	1941.0	--	--	--	--	--	--	--	--
82	1:00	2060.3	2018.7	191.74	4457	209.35	1.96	211.31	.05	211.36
83	1:15	2008.9	1966.7	186.80	4497	207.16	1.96	209.12	.10	209.22
BS 1	1:30	1942.7	--	--	--	--	--	--	--	--

November 14, 1978

BS 1	10:20	1962.1	1900.0	180.46	4460	198.28	4.56	202.84	.06	202.90
84	10:40	2064.1	2001.1	190.06	4438	206.37	1.30	207.67	0	207.67
85	10:50	2074.5	2011.0	191.00	4427	206.56	.65	207.21	0	207.21
86	11:00	2076.5	2012.6	191.16	4433	207.13	.65	207.78	.01	207.79
87	11:05	2062.7	1998.6	189.83	4449	206.90	1.30	208.20	.01	208.21
BS 1	11:20	1964.3	--	--	--	--	--	--	--	--
88	11:40	2090.9	2027.7	192.59	4455	210.07	1.30	211.37	.02	211.39
89	11:55	2088.1	2024.0	192.24	4453	209.58	.65	210.23	.02	210.25
90	12:00	2071.8	2007.7	190.69	4461	208.58	.65	209.23	.03	209.26
91	12:10	2069.7	2005.6	190.49	4458	208.17	1.30	209.47	.03	209.50
BS 1	12:20	1964.1	--	--	--	--	--	--	--	--
92	12:40	2048.5	1984.3	188.47	4471	207.04	.65	207.69	.04	207.73
93	12:50	2027.8	1963.6	186.50	4493	206.58	.65	207.23	.06	207.29
94	1:15	2005.3	1940.6	184.32	4511	205.64	1.30	206.94	.09	207.03
95	1:30	2052.7	1987.5	188.77	4495	208.99	2.44	211.43	.10	211.53
96	1:40	1926.5	1860.9	176.75	4597	203.96	2.44	206.40	.13	206.53
97	1:50	2064.9	1999.8	189.94	4458	207.62	2.61	210.23	.03	210.26
BS 1	2:00	1965.9	--	--	--	--	--	--	--	--
98	2:30	1960.6	1895.2	180.01	4604	207.70	3.26	210.96	.14	211.10
BS 1	3:15	1964.1	--	--	--	--	--	--	--	--

Table 1. Data Reduction and Gravity Corrections (continued)

Station Number	Time Read	Dial Divisions Average Reading	Dial Divisions Corrected for Drift	Milligals	Elevation (feet)	Bouguer Correction (= 2.0)	Latitude Correction (43 00)	Corrected through Latitude	Terrain Correction	G
				November 14, 1978 (cont'd.)						
*48	4:00	1704.6	1638.0	155.58	4947	206.78	6.52	213.30	.45	213.75
BS 1	4:35	1969.2	--	--	--	--	--	--	--	--
				November 16, 1978						
BS 1	10:45	1948.9	1900.0	180.46	4460	198.28	4.56	202.84	.06	202.90
99	11:40	1832.4	1783.3	169.38	4729	205.64	4.56	210.20	.30	210.50
100	12:15	1799.7	1750.4	166.25	4715	201.55	4.56	206.11	.30	206.41
BS 1	12:50	1949.7	--	--	--	--	--	--	--	--
101	1:10	1825.4	1775.4	168.63	4779	208.31	4.56	212.87	.36	213.23
102	2:25	1789.9	1738.4	165.11	4810	206.92	5.22	212.14	.33	212.47
103	2:40	1783.4	1731.5	164.46	4787	204.69	5.87	210.56	.34	210.90
104	2:55	1695.2	1642.9	156.04	4944	207.03	5.22	212.25	.43	212.68
105	3:15	1698.9	1646.0	156.34	4941	207.13	4.56	211.69	.42	212.11
BS 1	3:45	1953.6	--	--	--	--	--	--	--	--
				November 21, 1978						
BS 1	10:00	1949.8	1900.0	180.46	4460	198.28	4.56	202.84	.06	202.90
106	10:25	1898.5	1848.2	175.54	4631	205.08	4.56	209.64	.24	209.88
107	10:32	1896.8	1846.4	175.37	4560	200.04	4.56	204.60	.18	204.78
BS 1	10:55	1950.9	--	--	--	--	--	--	--	--
108	11:47	1888.3	1836.3	174.41	4646	204.98	3.26	208.24	.22	208.46
109	12:00	1853.9	1801.8	171.13	4675	203.69	2.61	206.30	.23	206.53
110	12:13	1860.1	1807.7	171.70	4683	204.80	2.28	207.08	.23	207.31
111	12:25	1930.8	1878.3	178.40	4602	205.95	1.96	207.91	.24	208.15
BS 1	12:55	1952.8	--	--	--	--	--	--	--	--

112	1:43	1813.2	1760.6	167.22	4750	204.92	3.26	208.18	.28	208.46
113	2:05	1732.5	1680.1	159.58	4892	207.01	3.26	210.27	.36	210.63
42	2:22	1703.9	1651.6	156.87	4949	208.21	3.26	211.47	.43	211.90
BS 1	2:49	1952.1	--	--	--	--	--	--	--	--
114	3:12	2049.0	1995.7	189.65	4440	206.10	1.30	207.04	0	207.04
115	3:22	2069.8	2017.2	191.60	4430	207.36	.65	208.01	0	208.01
116	3:30	2073.4	2020.4	191.90	4430	207.66	.65	208.31	0	208.31
BS 1	3:45	1953.8	--	--	--	--	--	--	--	--

December 12, 1978

BS 1	9:00	1957.2	1900.0	180.46	4460	198.28	4.56	202.84	.06	202.90
117	10:00	1694.0	1636.8	155.46	4954	207.14	5.87	213.01	.42	213.43
118	10:30	1741.4	1684.2	159.97	4854	204.80	6.52	211.32	.36	211.68
119	10:50	1733.0	1675.8	159.17	4730	195.50	6.52	202.02	.25	202.27
BS 1	11:20	1957.3	--	--	--	--	--	--	--	--
BS 1	12:20	1958.7	--	--	--	--	--	--	--	--
120	12:50	1758.5	1698.7	161.34	4642	191.63	6.52	198.15	.14	198.29
BS 1	1:10	1960.5	--	--	--	--	--	--	--	--
121	1:55	1789.4	1727.9	164.12	4628	193.46	5.87	199.33	.18	199.51
122	2:10	1841.2	1779.5	169.02	4642	199.31	5.22	204.53	.20	204.73
BS 1	2:35	1962.0	--	--	--	--	--	--	--	--
* 86	2:50	2078.1	2015.8	191.46	4433	207.43	.65	208.08	.01	208.09
* 77	3:05	2042.9	1980.1	188.07	4454	205.48	1.96	207.44	0	207.44
* 9	3:30	2030.6	1966.7	186.80	4465	204.96	3.26	208.22	0	208.22
* 13	3:40	2015.3	1950.7	185.28	4463	203.31	3.26	206.57	.03	206.60
BS 1	3:50	1965.3	--	--	--	--	--	--	--	--

January 30, 1979

BS 1	9:00	1999.4	1900.0	180.46	4460	198.28	4.56	202.84	.06	202.90
*46	10:41	1662.2	1560.4	148.21	5065	207.50	5.87	213.37	.51	213.88
**47	11:11	1639.8	1537.2	146.00	5094	207.27	6.52	213.79	.52	214.31
*118	12:05	1784.6	1680.2	159.59	4854	204.42	6.52	210.94	.36	211.30
BS 1	12:40	2005.9	--	--	--	--	--	--	--	--
BS 1	1:31	1008.9	--	--	--	--	--	--	--	--

Table 1. Data Reduction and Gravity Corrections (continued)

Station Number	Time Read	Dial Divisions Average Reading	Corrected for Drift	Milligals	Elevation (feet)	Bouguer Correction (= 2.0)	Latitude Correction (43 00)	Corrected through Latitude	Terrain Correction	G
				January 30, 1979 (continued)						
*25	1:50	1781.5	1672.9	158.89	4724	194.80	7.17	201.97	.26	202.23
*28	2:41	1629.6	1523.2	144.67	5102	206.56	7.17	213.73	.53	214.26
BS 1	3:25	2006.4	--	--	--	--	--	--	--	--
*112	4:20	1865.5	1758.8	167.05	4750	204.75	3.26	208.01	.28	208.29
*113	4:40	1786.4	1679.3	159.50	4892	206.93	3.26	210.19	.36	210.55
*42	4:55	1758.7	1651.3	156.84	4949	208.18	3.26	211.44	.43	211.87
BS 1	5:18	2008.0	--	--	--	--	--	--	--	--
				March 27, 1979						
BS 1	9:10	1902.6	1900.0	180.46	4460	198.28	4.56	202.84	.06	202.90
123	10:20	1744.81	1741.4	165.40	4842	209.40	2.50	211.90	.48	212.38
124	10:40	1682.8	1679.1	159.48	4920	208.83	2.14	210.97	.98	211.95
125	11:05	1772.7	1768.7	167.99	4779	207.67	2.70	210.37	.34	210.71
BS 1	12:07	1904.7	--	--	--	--	--	--	--	--
BS 1	1:04	1905.4	--	--	--	--	--	--	--	--
126	1:30	1920.6	1915.1	181.90	4541	205.27	1.37	206.64	.12	206.76
BS 1	1:53	1905.5	--	--	--	--	--	--	--	--

* Indicates duplicate station reading.
** Station not precisely located on second reading.

TABLE 2

GEOTHERMAL GRADIENT DATA FOR POCATELLO-TYHEE AREA

Depth (Meters)	Temperature °C	Depth (Meters)	Temperature °C
	Well 5S-35E-30aabl		
15	8.79	125	11.39
20	8.82	130	11.43
25	8.83	135	11.69
30	8.99	140	12.01
35	8.61	145	12.09
40	8.70	150	12.36
45	9.07	155	12.66
50	9.49	160	12.95
55	9.71	165	13.31
60	9.95	170	13.54
65	10.55	175	13.83
70	11.35	180	14.30
75	11.35	185	14.63
80	11.35	190	14.93
85	11.35	195	15.34
90	11.36	200	15.67
95	11.36	205	16.04
100	11.36	210	16.42
105	11.36	215	16.74
110	11.36	220	16.98
115	11.37	225	17.25
120	11.38	230	17.25
	Well 6S-34E-2cdcl		
0	9.38	35	12.84
5	9.97	40	13.22
10	12.06	45	13.76
15	12.03	50	13.86
20	12.17	55	13.94
25	12.28	60	14.09
30	12.41	65	14.12

Table 2. Geothermal Gradient Data for Pocatello-Tyhee Area (cont'd.)

Depth (Meters)	Temperature °C	Depth (Meters)	Temperature °C
	Well 5S-34E-36dacl		
10	10.57	125	23.57
15	10.57	130	23.84
20	11.59	135	24.26
25	17.09	140	24.77
30	17.31	145	25.28
35	17.63	150	25.78
40	17.88	155	26.22
45	18.12	160	26.58
50	18.51	165	26.94
55	19.00	170	27.12
60	19.46	175	28.19
65	19.77	180	28.21
70	20.22	185	28.22
75	20.45	190	28.22
80	20.71	195	28.23
85	20.79	200	28.23
90	21.17	205	28.23
95	21.43	210	28.24
100	21.61	215	28.24
105	22.08	220	28.24
110	22.59		
115	23.01		
120	23.37		
	Well 5S-34E-26dccl		
5	10.85	25	15.83
10	11.45	30	16.84
15	11.96	35	18.89
20	13.66	40	18.81
	Well 6S-35E-18caddl		
25	12.83	50	13.00
30	12.83	55	13.08
35	12.57	60	13.49
40	12.78	65	13.50
45	12.78	70	13.50

Table 2. Geothermal Gradient Data for Pocatello-Tyhee Area (cont'd.)

Depth (Meters)	Temperature °C	Depth (Meters)	Temperature °C
	Well 5S-34E-25cccl		
10	14.17	100	30.06
15	15.24	105	26.38
20	16.04	110	26.73
25	17.30	115	27.15
30	18.23	120	27.50
35	19.27	125	27.96
40	20.01	130	28.65
45	20.77	135	29.03
50	22.87	140	29.52
55	23.21	145	30.06
60	23.51	150	31.37
65	23.76	155	32.20
70	24.15	160	32.98
75	24.47	165	33.96
80	24.71	170	34.76
85	25.09	175	35.14
90	25.42	180	35.37
95	25.70	182	35.41
	Well 6S-35E-18cbbl		
10	11.17	80	12.24
15	11.81	85	12.25
20	11.68	90	12.27
25	11.87	95	12.28
30	11.99	100	12.29
35	12.05	105	12.31
40	12.10	110	12.32
45	12.13	115	12.46
50	12.16	120	12.51
55	12.18	125	12.51
60	12.20	130	12.51
65	12.21	135	12.55
70	12.22	140	12.55
75	12.23	145	12.55